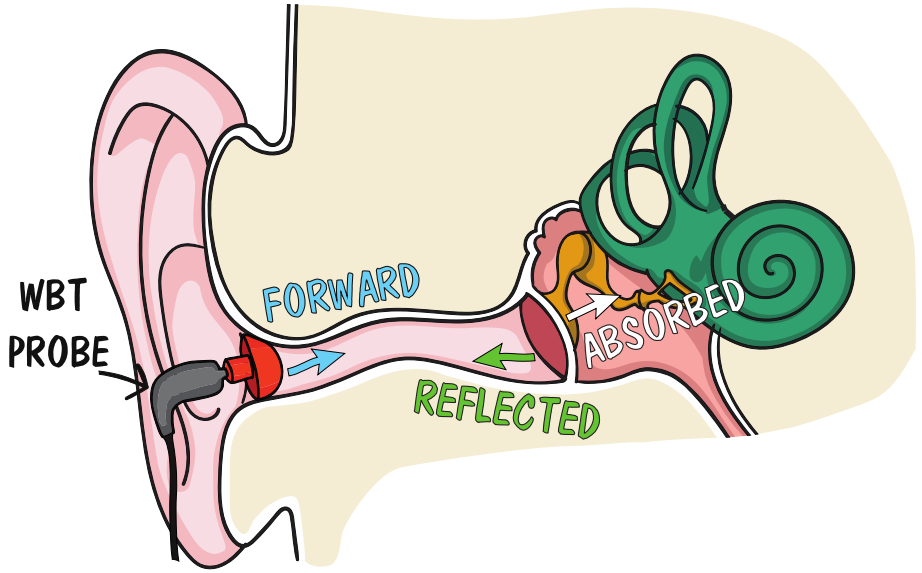
Wideband Acoustic Immittance: What is it, How do you measure it, and What can it tell us?

Gabrielle R. Merchant, Au.D., Ph.D., CCC-A
Scientist III, Center for Hearing Research
Director, Translational Auditory Physiology and Perception Laboratory
Boys Town National Research Hospital

TAA 2025

BOYS TOWN
National Research
Hospital®

What is Wideband Acoustic Immittance / Wideband Tympanometry?



- Wideband Tympanometry (WBT) is a measure of peripheral auditory mechanics. It utilizes a broadband stimulus to measure how effectively sound is transmitted through the middle ear system. Measurements are made in response to wideband sounds (200 – 8000 Hz).
- FDA approved
- **Absorbance**: Wideband absorbance refers to the amount of sound energy absorbed by the middle ear as a function of frequency.
- Can be done at ambient pressure or pressurized (i.e., downswept pressure)

BOYS TOWN National Research Hospital

Limitations in Standard Tympanometry

- 226 Hz tympanometry has demonstrated utility in determining the **presence or absence** of middle-ear abnormalities in clinic, but it is limited in further differentiation
- The standard 226 Hz probe tone is not always sufficient
  - Only tells you about low-frequency effects (stiffness effects)
  - Auditory system has input across a broad range of frequencies, so understanding how it responds across that range can be important
  - Newborn ears are not stiffness dominated like adult ears, so they need to be tested at a higher frequency
  - Pressurizing the ear canal can be problematic in newborns who have compliant ear canals (can result in a peak that isn't from the TM)
    - Have to pressurize in order to do compensation
- Of note – the low frequency stimulus used in standard tympanometry was chosen out of convenience (made the calibration simple!), not because it provided the best clinical information

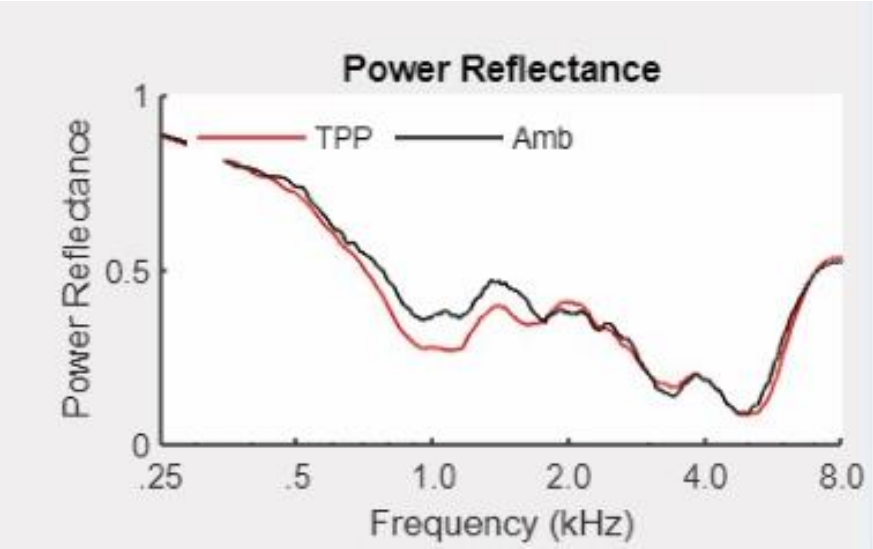
WAI/WBT Overcomes All Major Limitations in Tympanometry

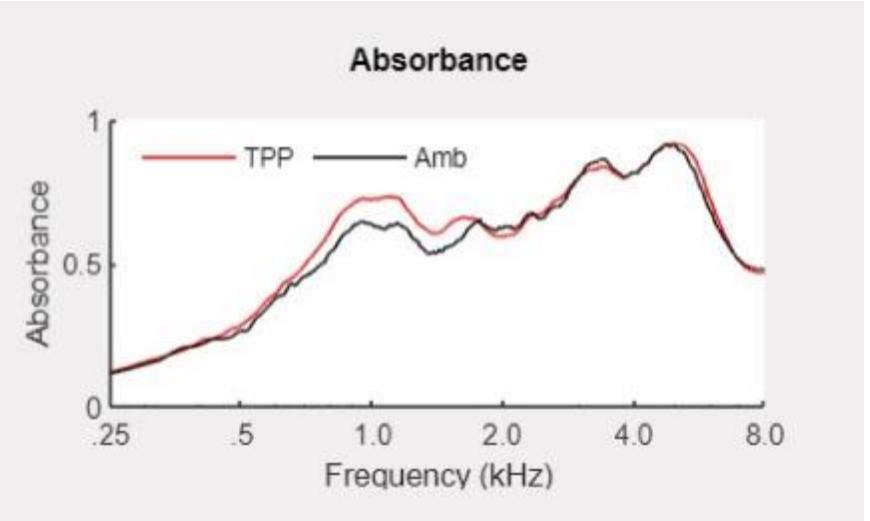
- Only tells you about low-frequency effects (stiffness effects)
  - WAI uses a wideband stimulus so it tells you about mechanical effects across frequency
- Auditory system has input across a broad range of frequencies, so understanding how it responds across that range can be important
  - Wideband stimulus
- Newborn ears are not stiffness dominated like adult ears, so they need to be tested at a higher frequency
  - Can extract information at any frequency of interest!
- Pressurizing the ear canal can be problematic in newborns who have compliant ear canals
  - Can pressurize, but don't have to!

Terminology

- Wideband Acoustic Immittance (WAI)
  - **Power Reflectance**, Ear-Canal Reflectance, Energy Reflectance
  - **Absorbance**, Transmittance
  - **Wideband Tympanometry (WBT)**
  - PR and Absorbance are common forms of WAI as they are theoretically insensitive to measurement location.

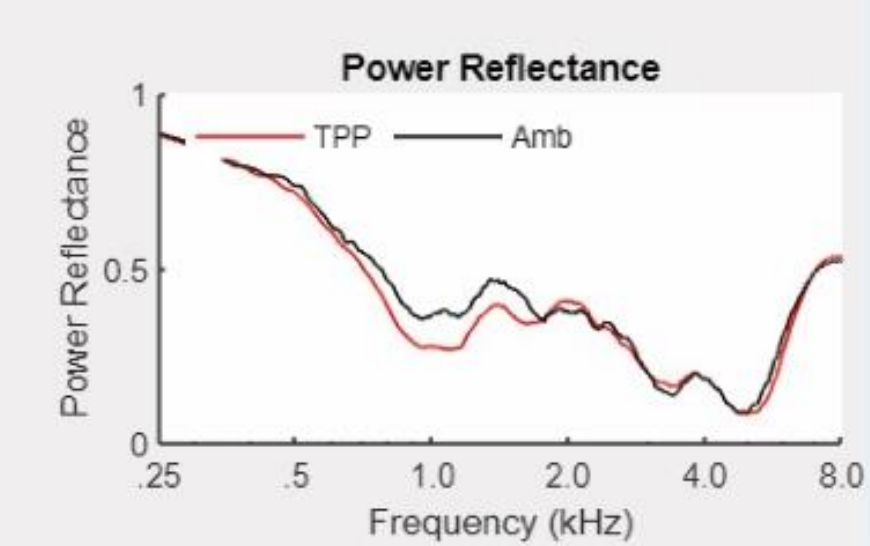
Power Reflectance vs. Absorbance

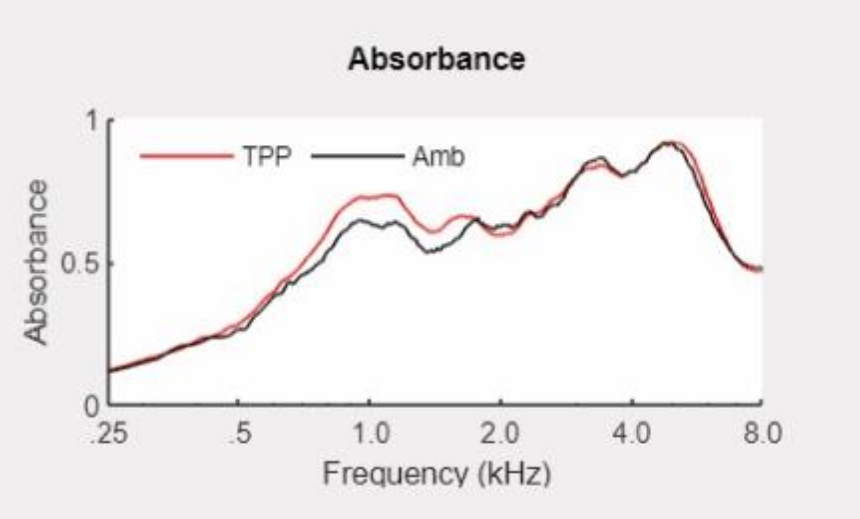


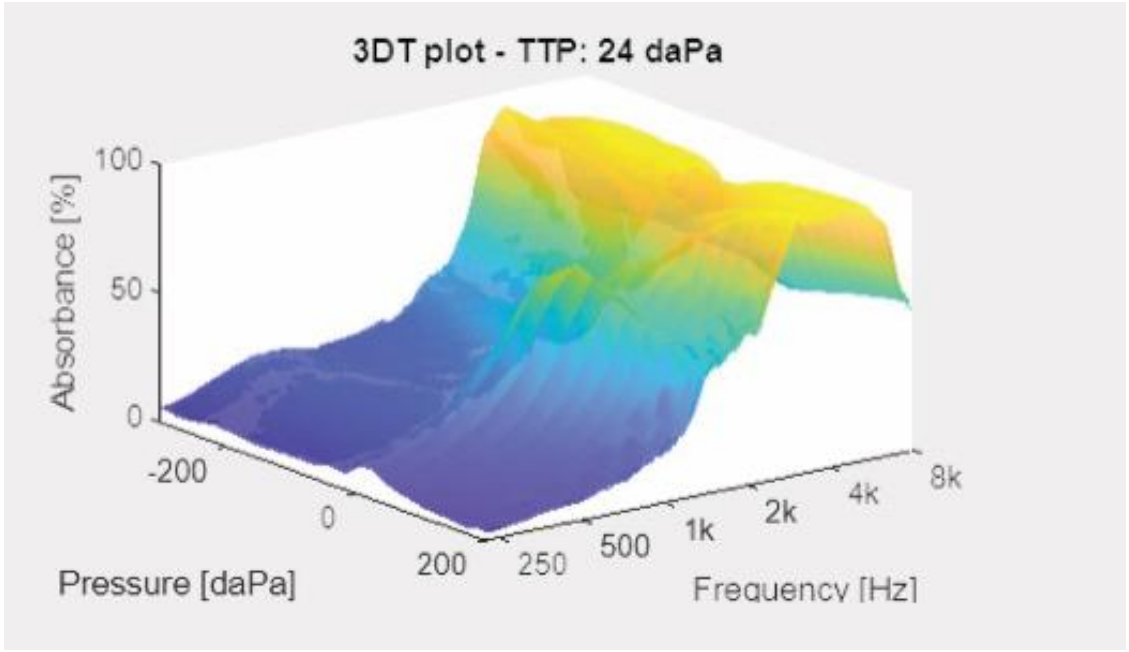


- Much of the early literature and research on WAI looked at Power Reflectance as the outcome parameter. More recently, there has been a transition to looking at Absorbance instead. Absorbance is the opposite of reflectance – it is simply the graph flipped over. It was thought that this might be more intuitive in clinic.
- The Titan output is in Absorbance. So, while much of some of the you will find in the literature is in the Power Reflectance world, you would just think have to think about flipping the graph over to be in the Absorbance world.

Ambient vs Pressurized WAI (aka WBT)







- If we add tympanometry to these measurements, we get a 3D result with absorbance across frequency at various pressures. We can extract tympanograms at different frequencies or absorbance responses at different pressures.
- For absorbance, we usually look at 0 daPa (ambient pressure) and TPP. By looking at TPP, you can remove the impact of static pressure on WAI and see if there is any additional evidence of pathology.

BOYS TOWN National Research Hospital

Why do we care about characterizing the mechanics (and impedance of the system) across a wide frequency range?

- We think a lot about impedance when it comes to the middle ear. The purpose of the middle ear is to match the low impedance of air (what sounds are traveling through in the outer and middle ear) to the higher impedance of fluid of the inner ear.
  - How? 1) Ratio of the area of the tympanic membrane and the oval window and 2) Lever action of two middle ear bones, the malleus and the incus.
- Pathological changes in the ear can also change the impedance of system in a variety of ways and measuring those changes can be diagnostically useful!

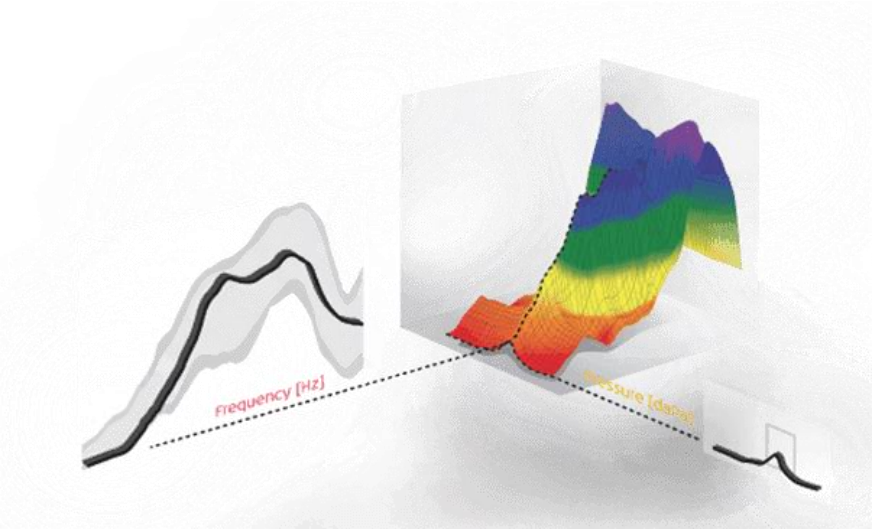
Impact on Audiometry

- Impedance of the middle-ear system is dominated by
  - **Stiffness** for the lower frequencies
  - **Mass** for the higher frequencies
  - Remember: Stiff systems pass high frequencies and offer high impedance at low frequencies. Thus the impedance of the system at low frequencies is mostly from the stiffness of the system, since that is what provides high impedance there. (The opposite happens at high frequencies with mass).
- This is why pure-tone audiometry yields
  - a low frequency (conductive) hearing loss if there is a *higher-than normal stiffness component,* such as found with otosclerosis.
  - a rarer high frequency conductive hearing loss if there is greater-than-normal mass on the ossicular chain.

Wideband Acoustic Immittance: What is it, How do you measure it, and what can it tell us?

BOYS TOWN National Research Hospital

Interacoustics Titan System



- Wideband Tympanometry (200-8000 Hz), OAEs, ABRIS

GSI Tympstar

BOYS TOWN
National Research
Hospital

Titan Suite - Standalone

Menu

Absorbance + 3DT

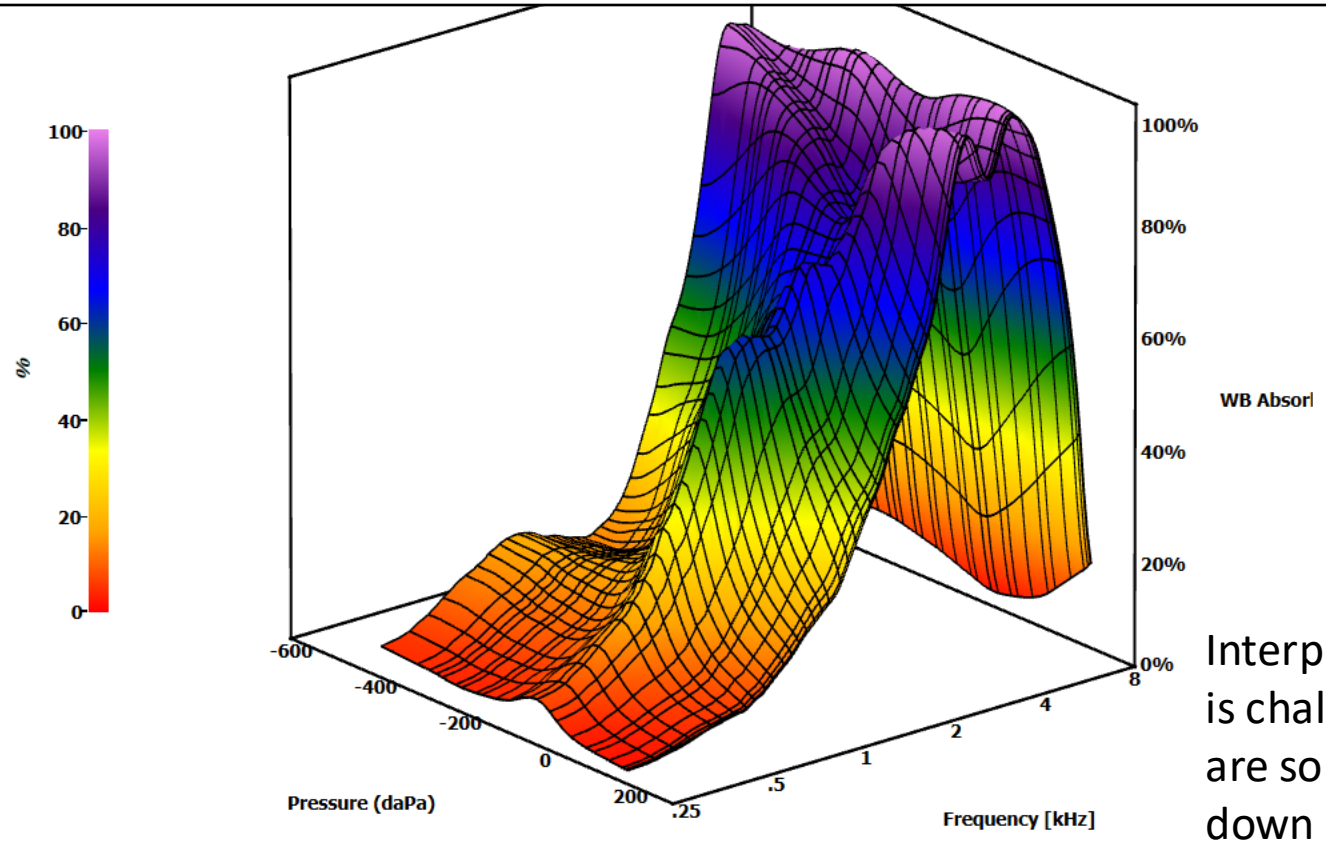
Current session

In ear

WRT Adult

3D graph | Tympanograms | Absorbances

What 3DT results look like. First up, the 3D graph tab.



Interpreting the 3D graph is challenging, but there are some useful values down here (RF, ECV, TPP)

WB Absorbance

3D Tympanometry

START

Draw pressure line (tymp)
Tymp view
Draw pressure line at 226 Hz

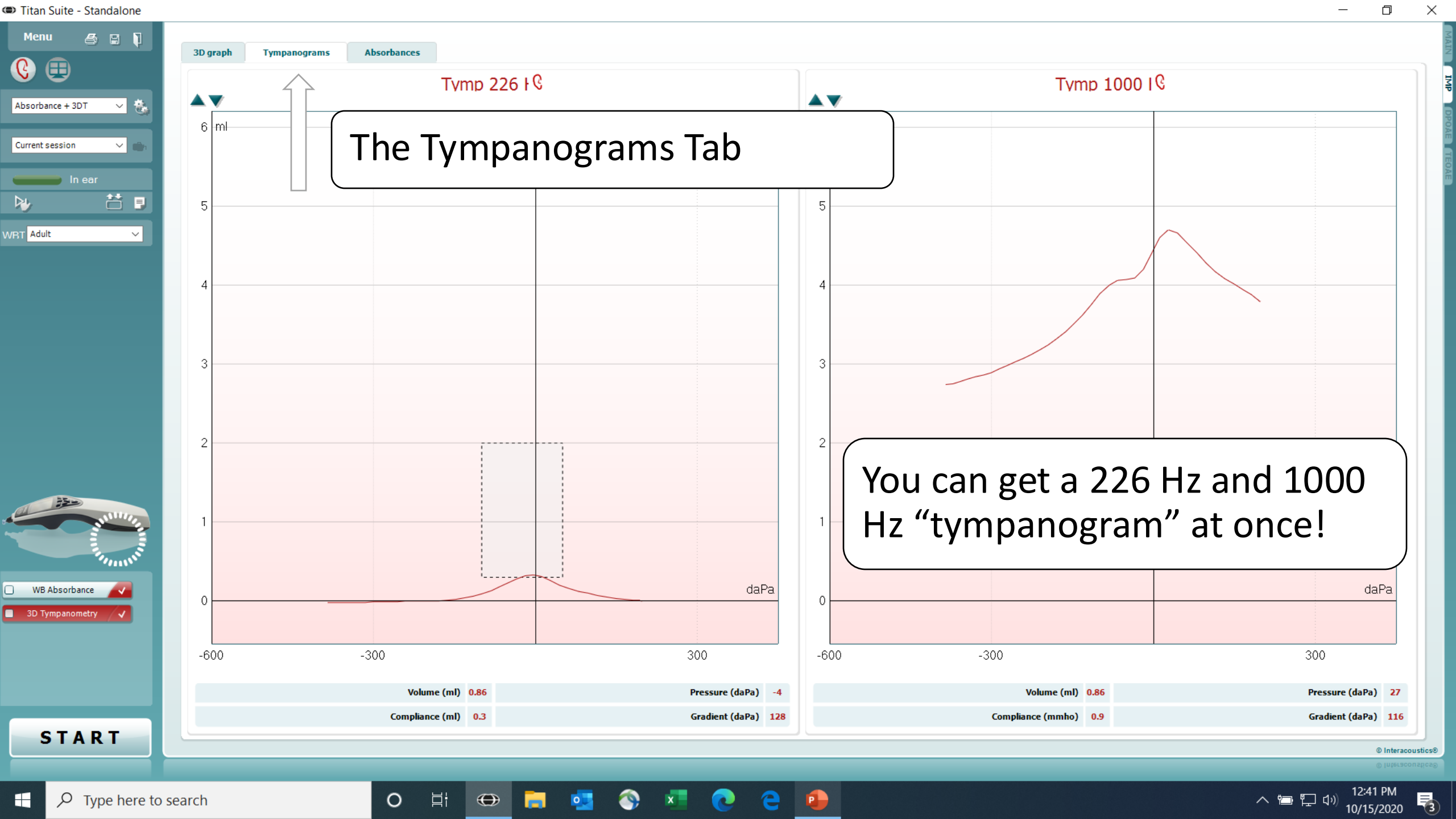
Draw absorbance line
Absorbance view
Draw absorbance line at -4 daPa

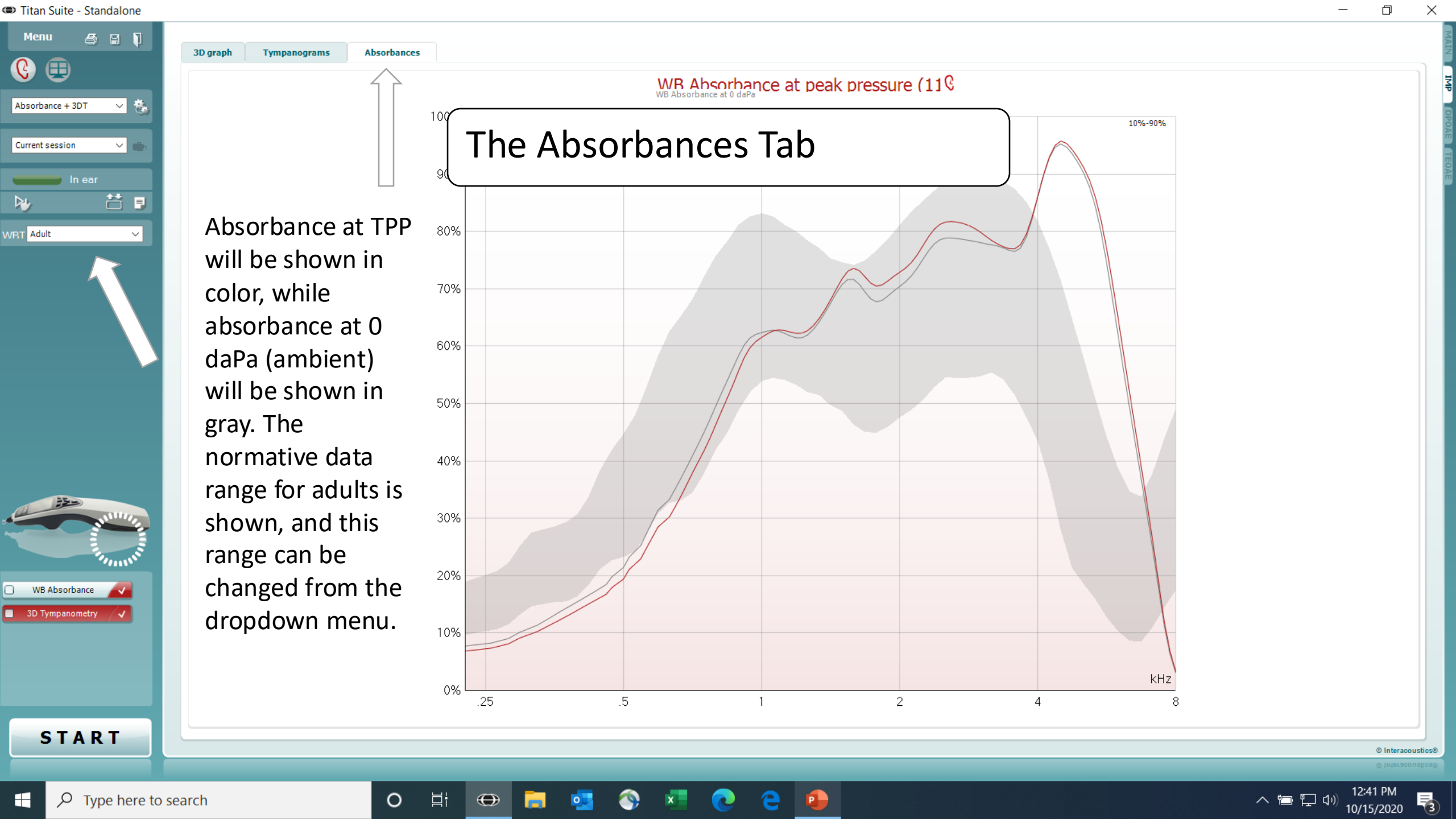
Equivalent ear canal volume: 0.86 ml
Resonance frequency: 977 Hz
Peak pressure: 11 daPa
C: 226 Hz: 0.3 ml, 1000 Hz: 0.91 mmho

© Interacoustics®

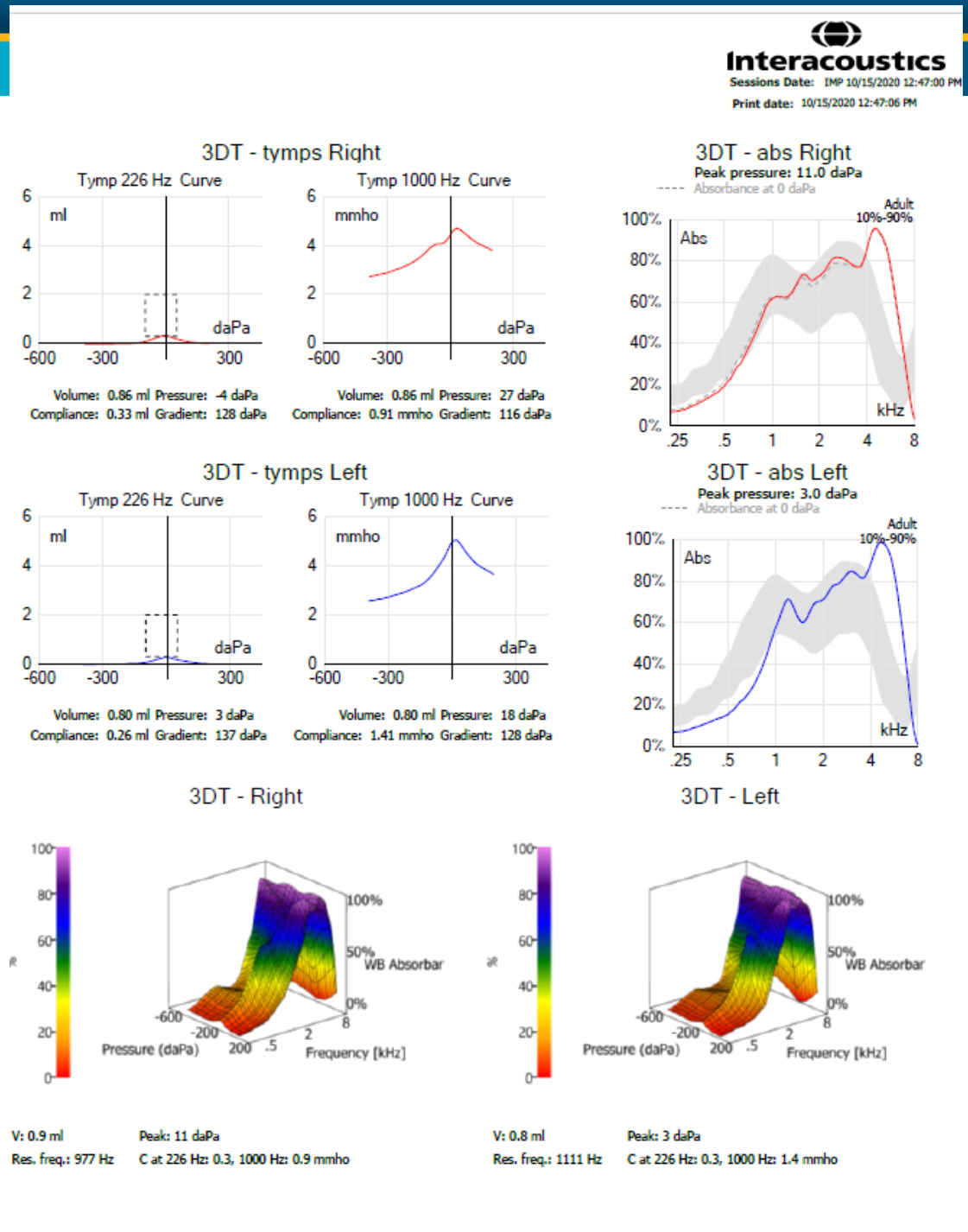
Type here to search

12:41 PM
10/15/2020


Titan Suite - Standalone
Menu
Absorbance + 3DT
Current session
In ear
WRT
Adult
WB Absorbance
3D Tympanometry
START
3D graph
Tympanograms
Absorbances
Tymp 226 Hz
Tymp 1000 Hz
The Tympanograms Tab
You can get a 226 Hz and 1000 Hz “tympanogram” at once!
ml
daPa
Volume (ml) 0.86
Pressure (daPa) -4
Compliance (ml) 0.3
Gradient (daPa) 128
Volume (ml) 0.86
Pressure (daPa) 27
Compliance (mmho) 0.9
Gradient (daPa) 116
© Interacoustics®
Type here to search
12:41 PM
10/15/2020


Titan Suite - Standalone
Menu
3D graph
Tympanograms
Absorbances
Absorbance + 3DT
Current session
In ear
WRT
Adult
WB Absorbance
3D Tympanometry
START
The Absorbances Tab
Absorbance at TPP will be shown in color, while absorbance at 0 daPa (ambient) will be shown in gray. The normative data range for adults is shown, and this range can be changed from the dropdown menu.
WB Absorbance at peak pressure (11
WB Absorbance at 0 daPa
10%-90%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
.25
.5
1
2
4
8
kHz
© Interacoustics®
Type here to search
12:41 PM
10/15/2020

Sample Report



BOYS TOWN National Research Hospital

Billing Considerations $$$

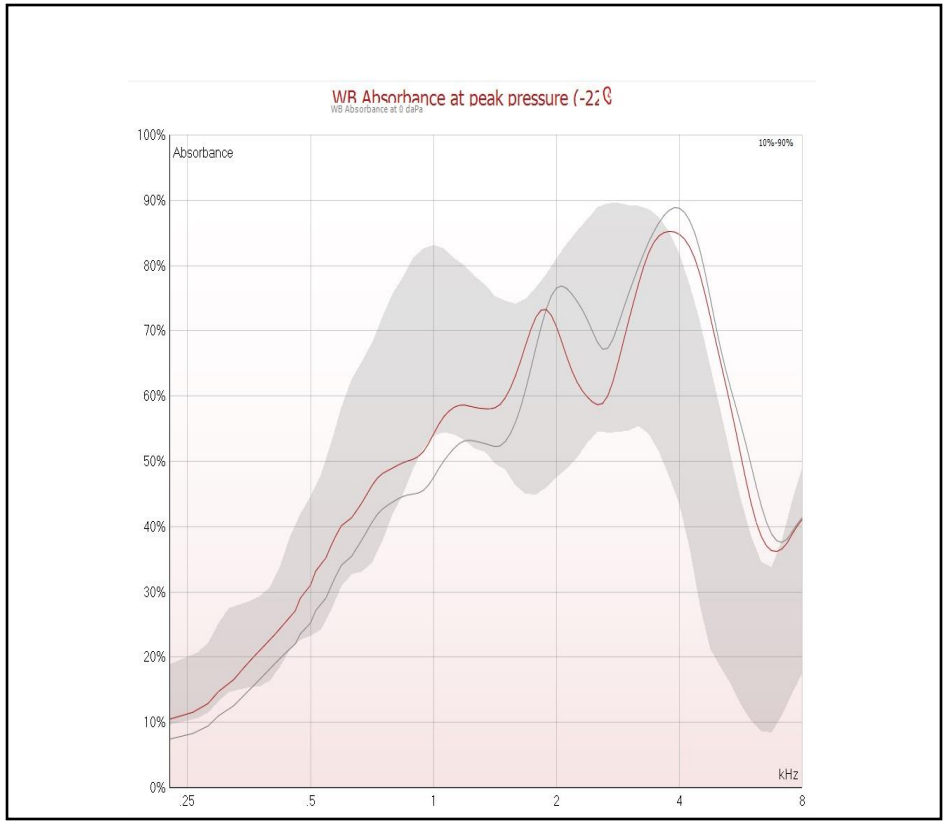
- There are no current CPT codes for wideband reflectance and multi-frequency tympanometry tests.
- The tympanometry-only code (92567) should be used if WBT testing is completed.
  - Please note, this code is session-based, meaning it can only be billed one time per encounter, even if standard tympanometry and WBT are completed in the same visit.
- An extended service modifier (-22) could be considered when multi-frequency tympanometry and wideband reflectance testing are completed on the same day.
  - Detailed documentation of the justification for these extended services should be included in the visit report.

Wideband Acoustic Immittance: What is it, How do you measure it, and what can it tell us?

BOYS TOWN National Research Hospital

Basic Big Picture: What does WBT tell us?

- Big picture (these are not hard and fast rules and are oversimplifications, but hopefully helpful):
- If absorbance is ***decreased***
  - At low frequencies - the system is stiffer (e.g., otosclerosis)
  - At high frequencies - there is increased mass (e.g., cholesteatoma)
  - Across frequency - there is both increased stiffness and mass (e.g., otitis media)
- If absorbance is ***increased***
  - At low frequencies - the system is more compliant (e.g., disarticulation)
    - *We often see this as low to mid frequency peak appearing in the response.*
  - At high frequencies - there is decreased mass (not very common)



BOYS TOWN National Research Hospital

Major Applications of WAI

- Newborn Hearing Screening
  - Reduction of False-Positives
  - CHL Detection in Infants
- Otitis Media
- Differential Diagnosis of CHL and Middle-Ear Pathologies
  - Otosclerosis, Other Fixation, Disarticulation, Superior Semicircular Canal Dehiscence, Middle-Ear Effusion, TM Perforation
- New… characterizing ear-canal acoustics to help predict things like RECDs (and maybe thresholds)

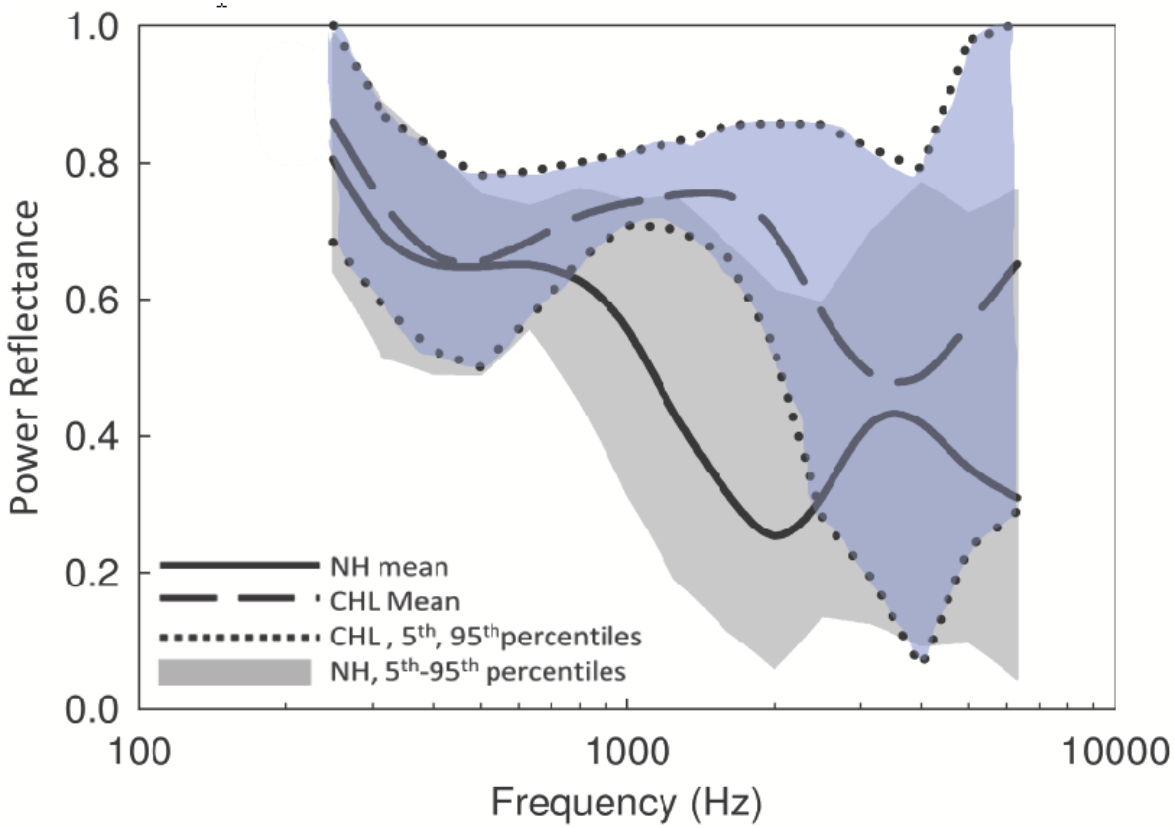
Newborn Hearing Screening

BOYS TOWN
National Research
Hospital

WAI & Newborn Hearing Screening

- Hearing loss is among the most common birth defect, affecting 1-6 out of every 1000 births
- UNHS has allowed for early detection of hearing loss, **but has a high false positive rate**, most commonly due to fluid
- Thus, a simple test of middle-ear status would be of great use during newborn hearing screening, and could be used in infants up to 6 mos, where tympanometry has shown to be unreliable
- Could help us flag infants who refer on the newborn screen but have normal middle-ear status as high priority versus who could benefit from a rescreen due to abnormal middle-ear status

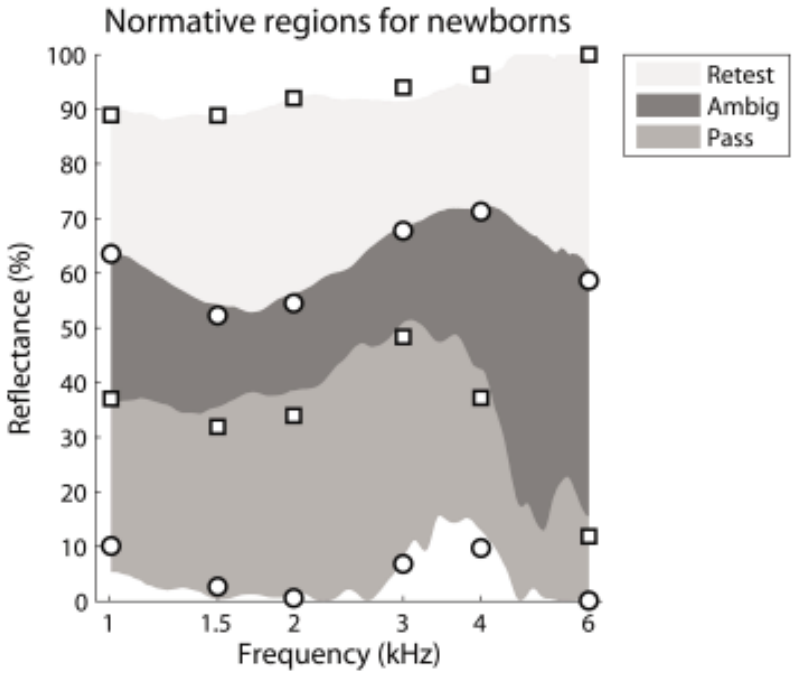
CHL Detection in Infants



- Infants with CHL (as determined by ABR) show increased PR at most frequencies.

Prieve et al 2013

CHL Detection in Infants



Adding WAI to the newborn screening protocol would be beneficial!

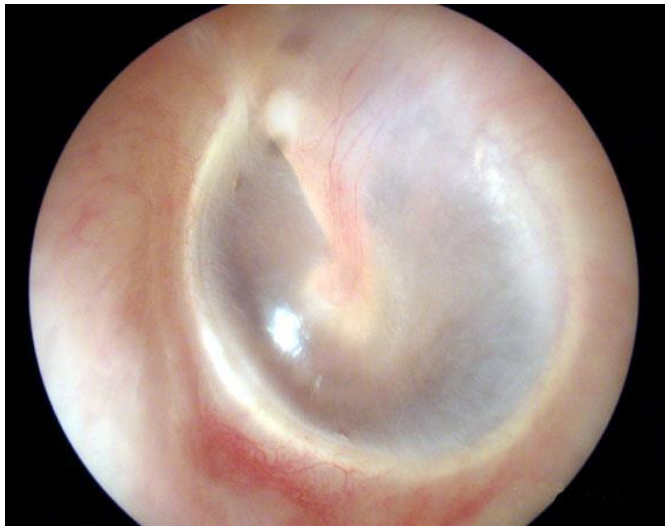
Hunter et al 2010, 2013

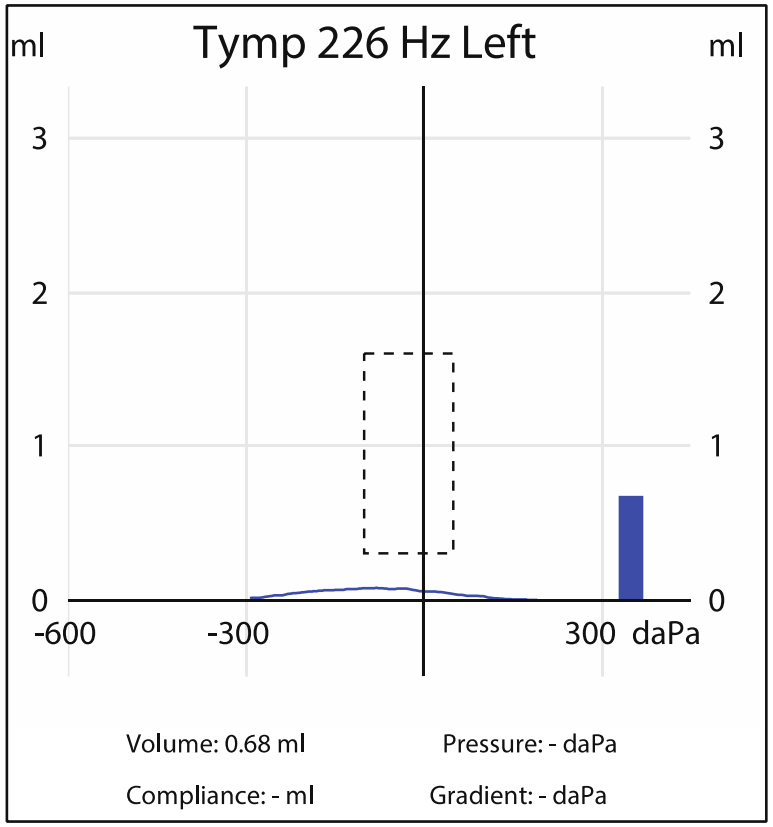
Overall DPOAE result	Reflectance at 2 kHz	Interpretation
pass	in pass region	pass - normal result
pass	above pass region (i.e., in the ambiguous or retest regions)	pass - may have middle-ear issues, but cochlear response is normal
refer	in pass region	refer - consistent with SNHL - needs follow-up referral
refer	above pass region (i.e., in the ambiguous or retest regions)	re-screening is indicated. Repeat MEPA to determine if middle ear issue is resolved.

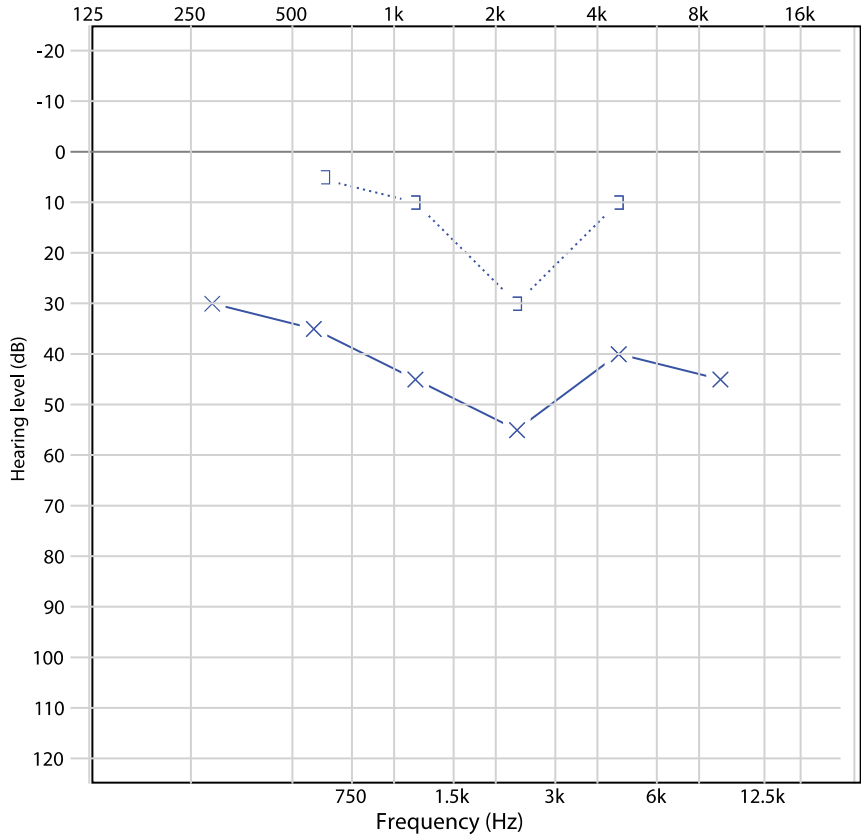
Otitis Media

BOYS TOWN
National Research
Hospital

A Clinical Dilemma: Patient A

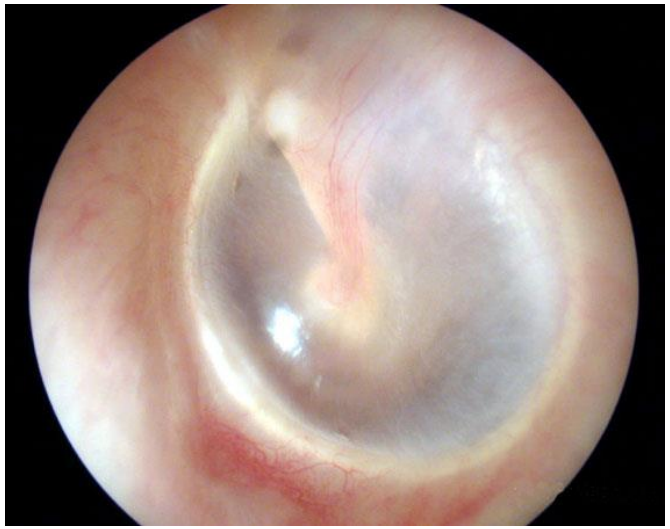


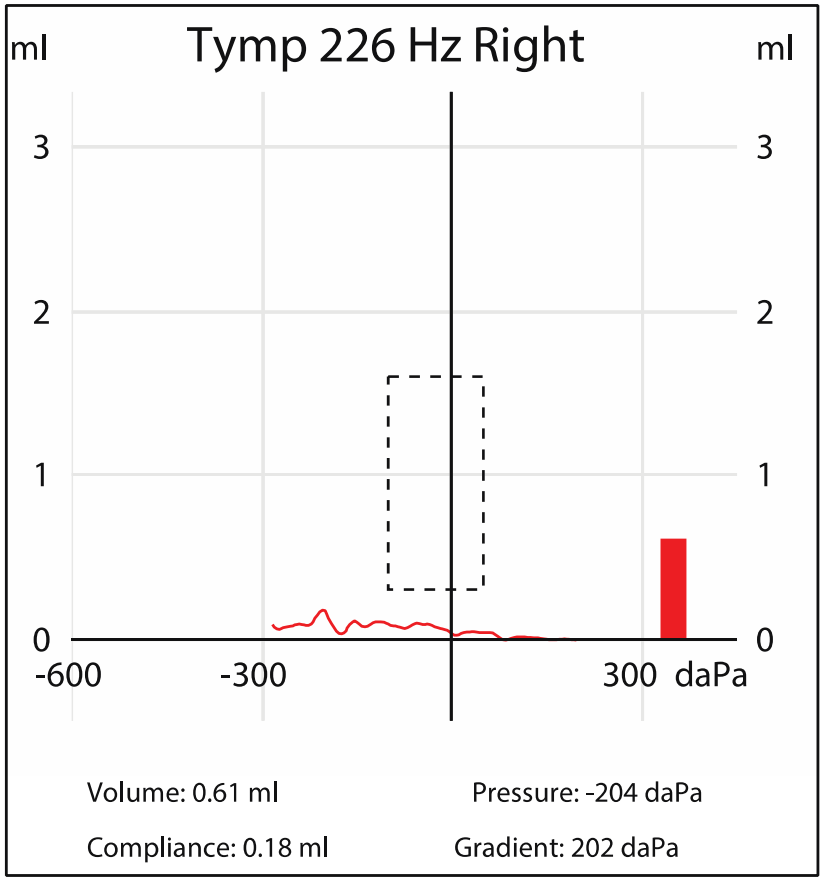


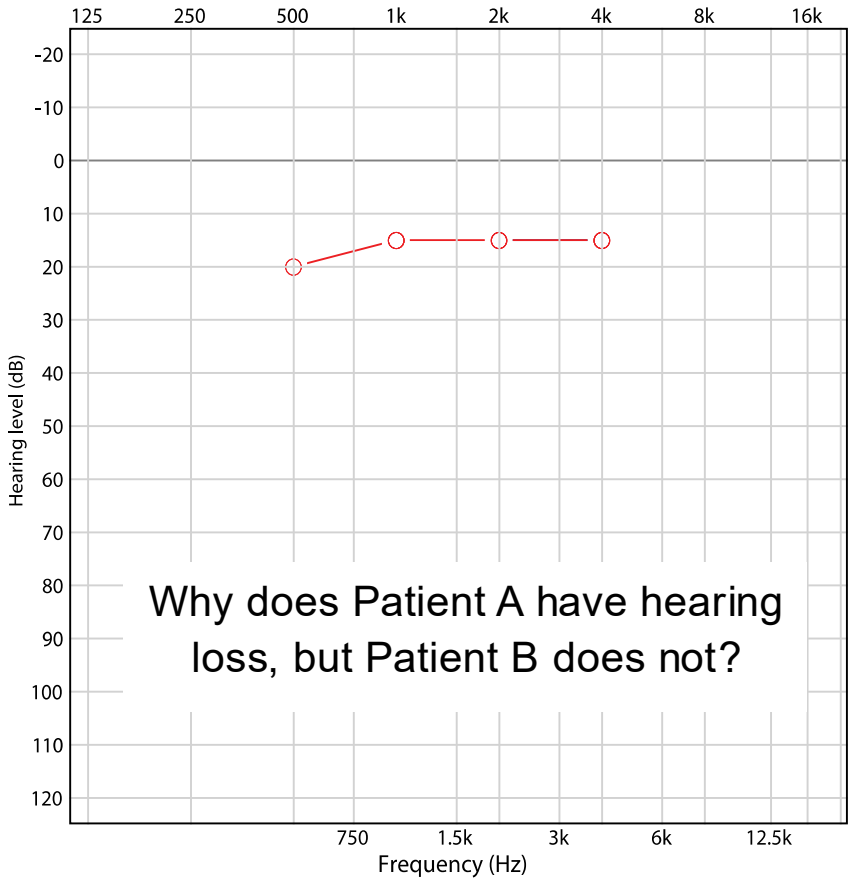


BOYS TOWN
National Research
Hospital

A Clinical Dilemma: Patient B

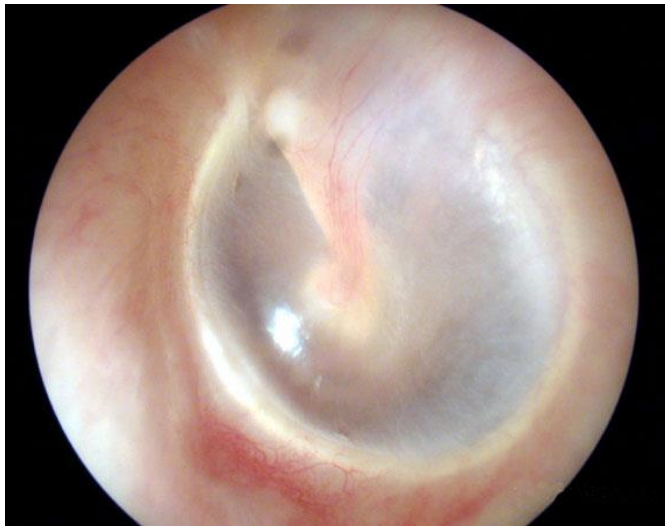


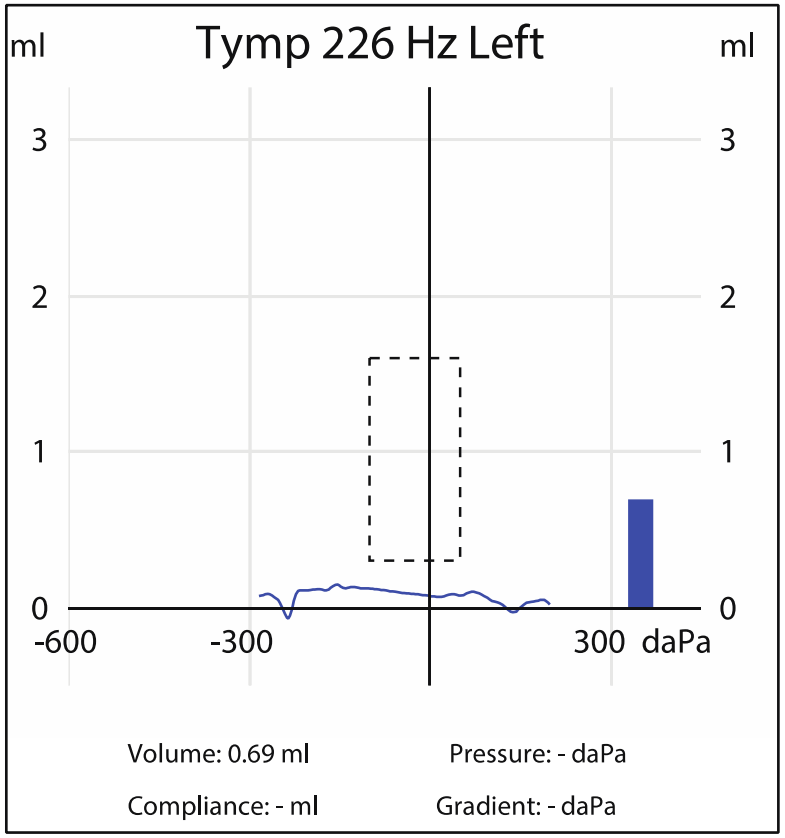




BOYS TOWN National Research Hospital

A Clinical Dilemma: Patient C



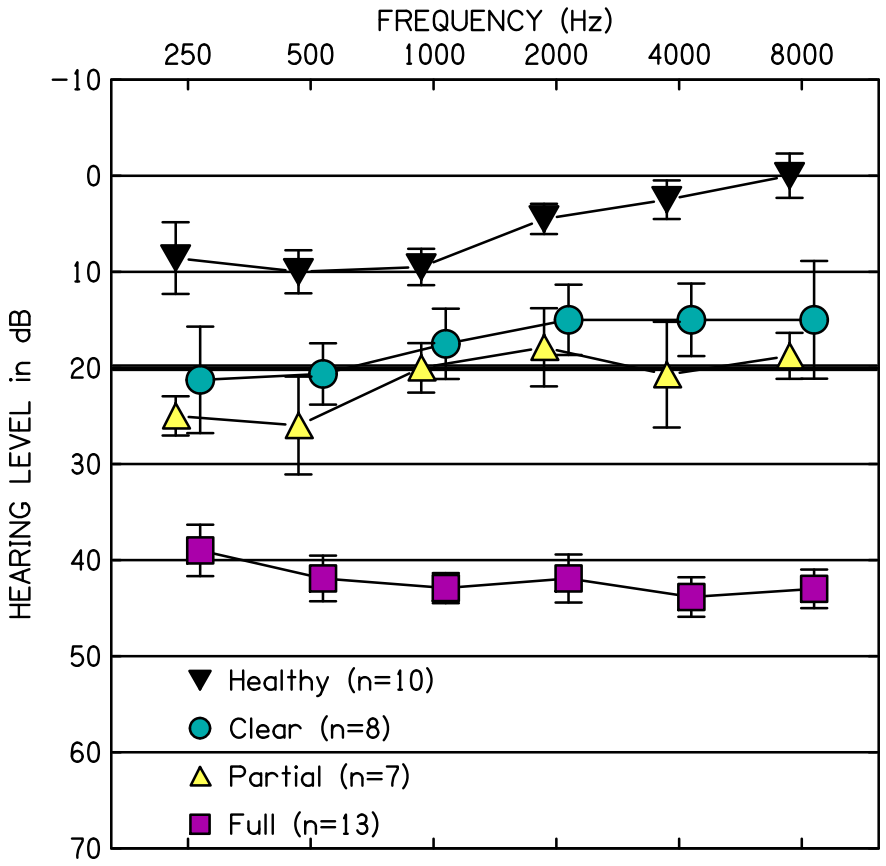


No reliable behavioral thresholds could be obtained

- Do they have hearing loss? Do they not?
  - Does it matter?

So, what have we learned about hearing loss in children with OME?

Effusion Volume Drives Hearing Loss



Normal

Clear/Empty

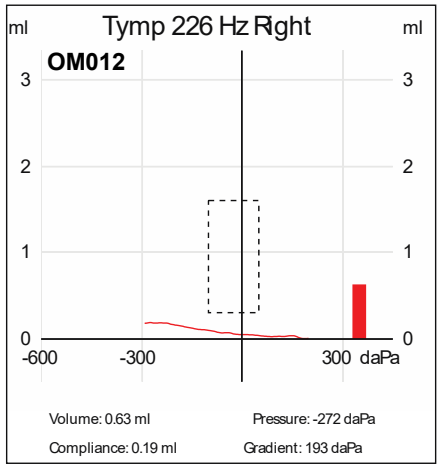
Partial Effusion

Full Effusion

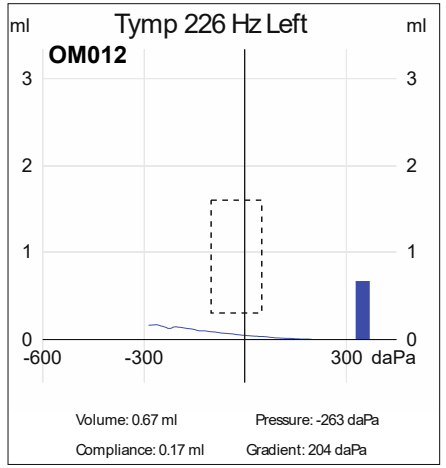
Middle-ear effusion volume drives hearing loss!

Al-Salim et al., 2021

Standard Tympanometry Can't Predict Effusion Volume



½ Mucoid Effusion (Partial)

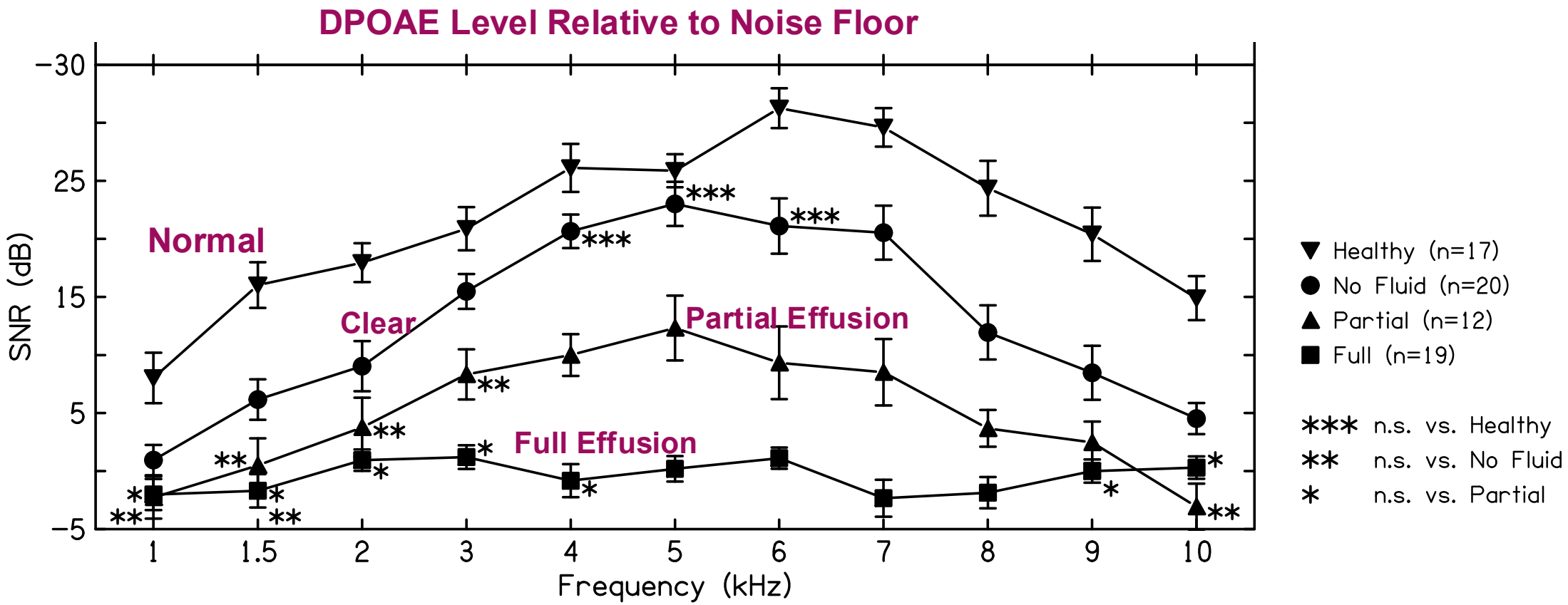


Full Mucoid Effusion

Al-Salim et al 2021

BOYS TOWN National Research Hospital

Effusion volume impacts DPOAEs, but somewhat differently than it does for hearing levels

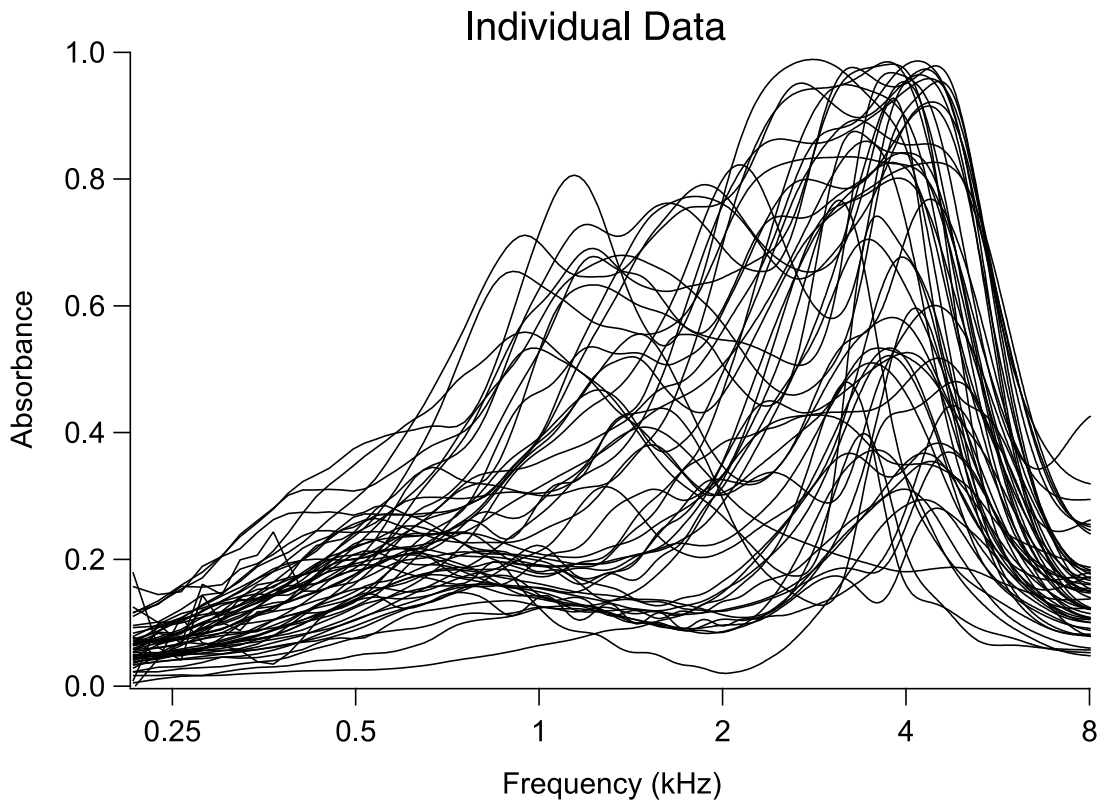


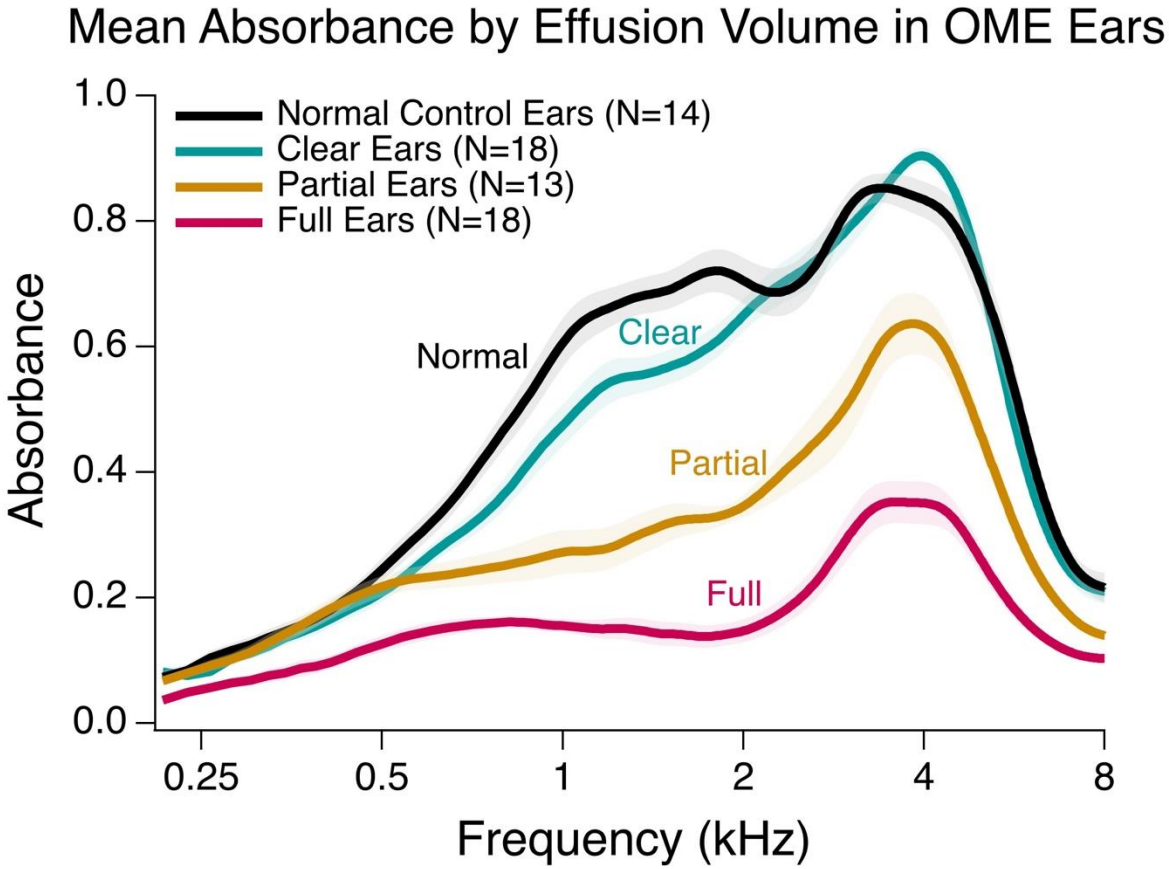
Separation between empty and partial ears, likely due to influence of both forward and reverse transmission for DPOAEs

Al-Salim et al 2021

BOYS TOWN National Research Hospital

Unlike Tympanometry, WBT Absorbance Shows Significant Promise in Predicting Effusion Volume



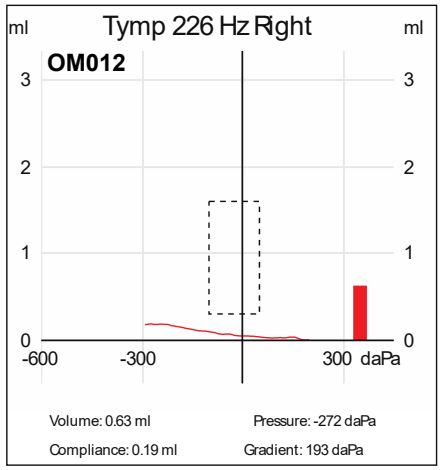


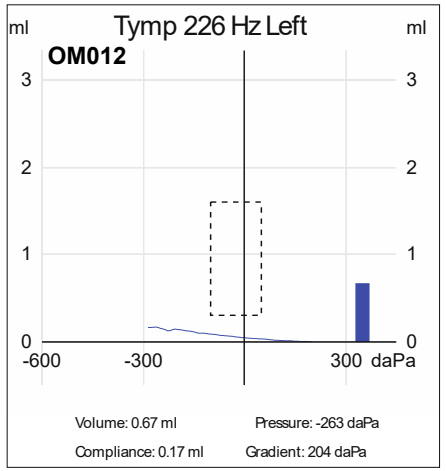
The influence of OME on auditory mechanics is highly variable when we look across frequency!

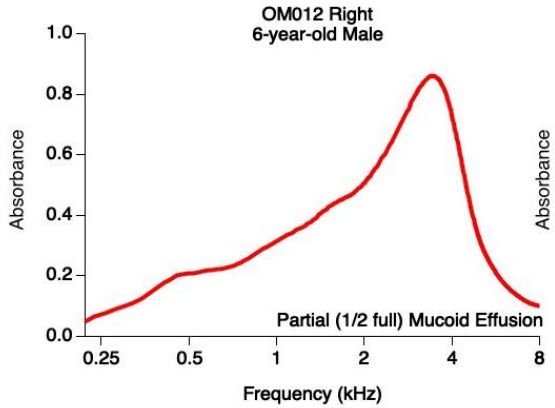
Merchant et al 2021

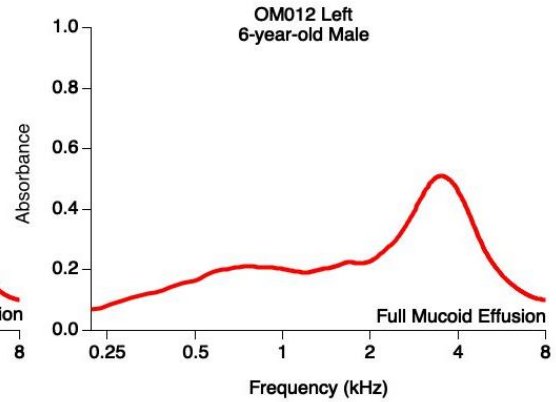
BOYS TOWN National Research Hospital

Unlike Tympanometry, WBT Absorbance Shows Significant Promise in Predicting Effusion Volume





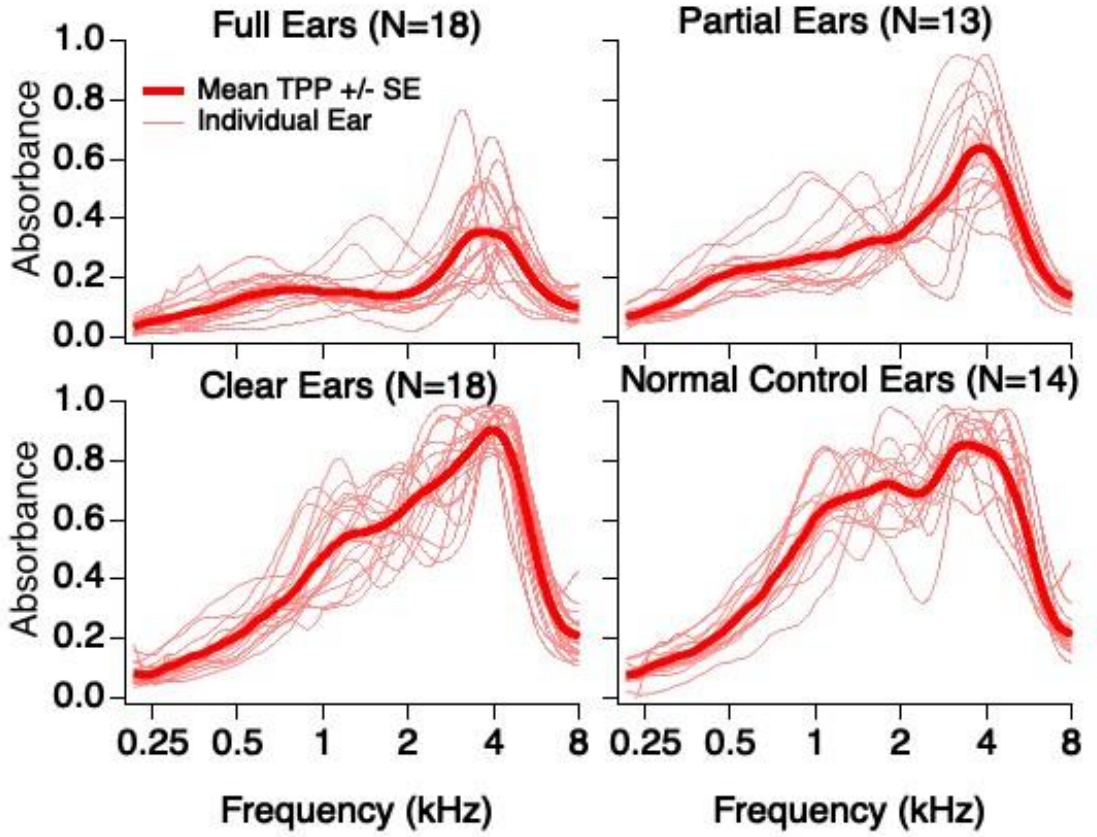




BOYS TOWN National Research Hospital

Predictions Are Also Strong in Individual WBT Data

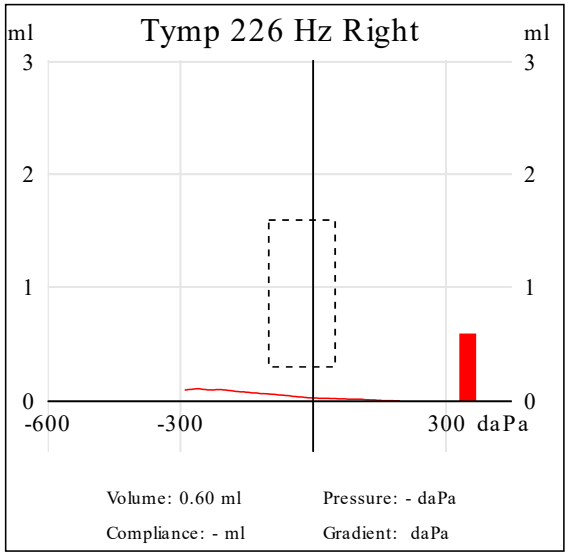
Results of a machine learning algorithm trained on 70% of the data (reduced using a PCA) and validated on 30% of the unseen data: high AUCs for effusion present vs absent and full vs. partial, moderate for clear vs. normal.

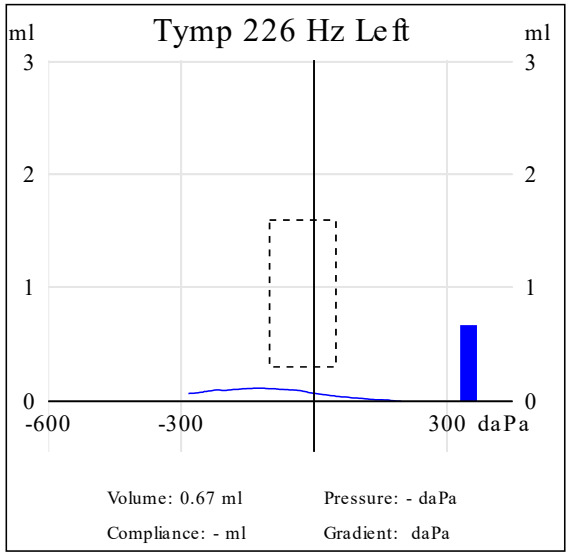


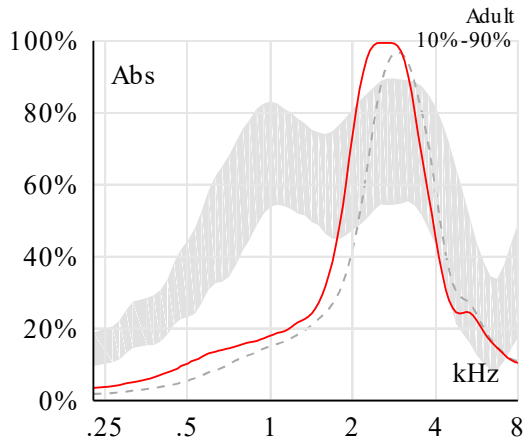
Effusion Present versus Absent			Partial versus Full Effusion			Clear versus Normal Ears		
Validation Confusion Matrix			Validation Confusion Matrix			Validation Confusion Matrix		
Accuracy: 95%, Sensitivity: 95%, Specificity: 95%, AUC: 0.988			Accuracy: 89%, Sensitivity: 89%, Specificity: 88%, AUC: 0.944			Accuracy: 65%, Sensitivity: 67%, Specificity: 62%, AUC: 0.689		
	Present	Absent		Full	Partial		Clear	Normal
Present	8459	541	Full	8459	541	Clear	3642	1358
Absent	439	9561	Partial	439	9561	Normal	1788	2212

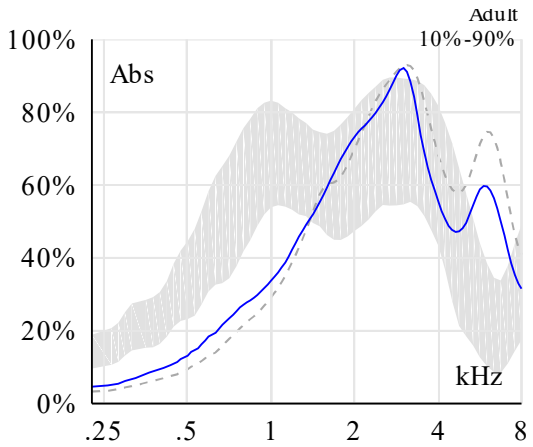
Merchant et al 2021

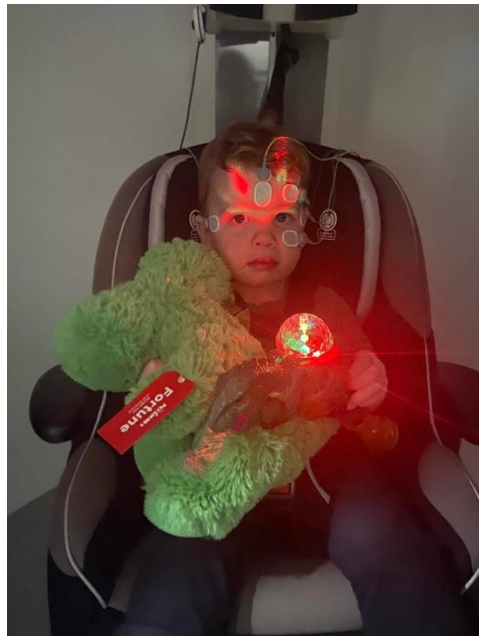
BOYS TOWN National Research Hospital





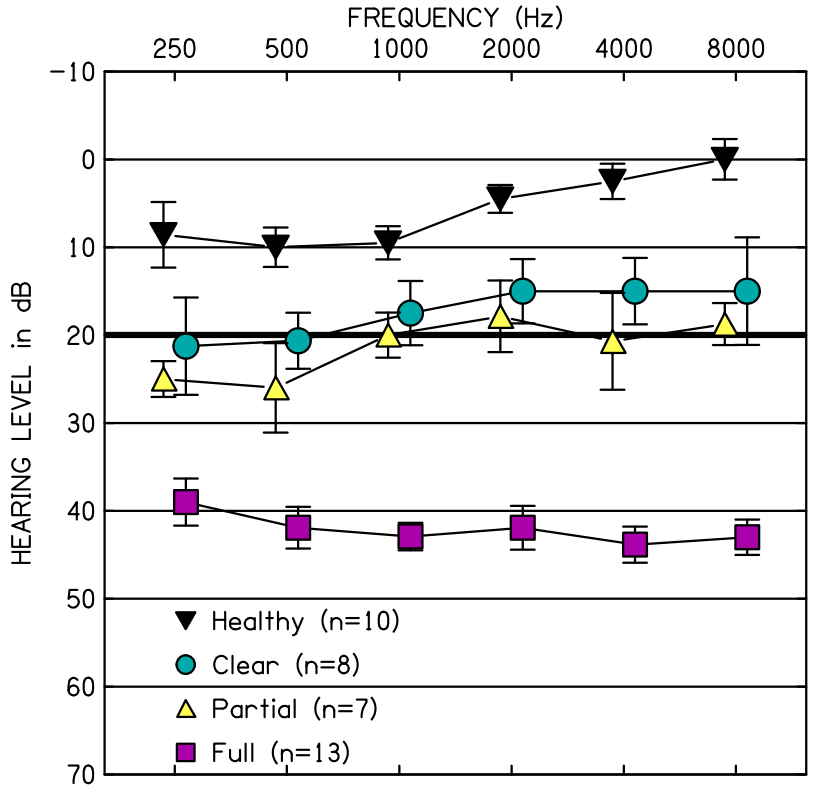






BOYS TOWN
National Research
Hospital

Why are these data exciting to us?

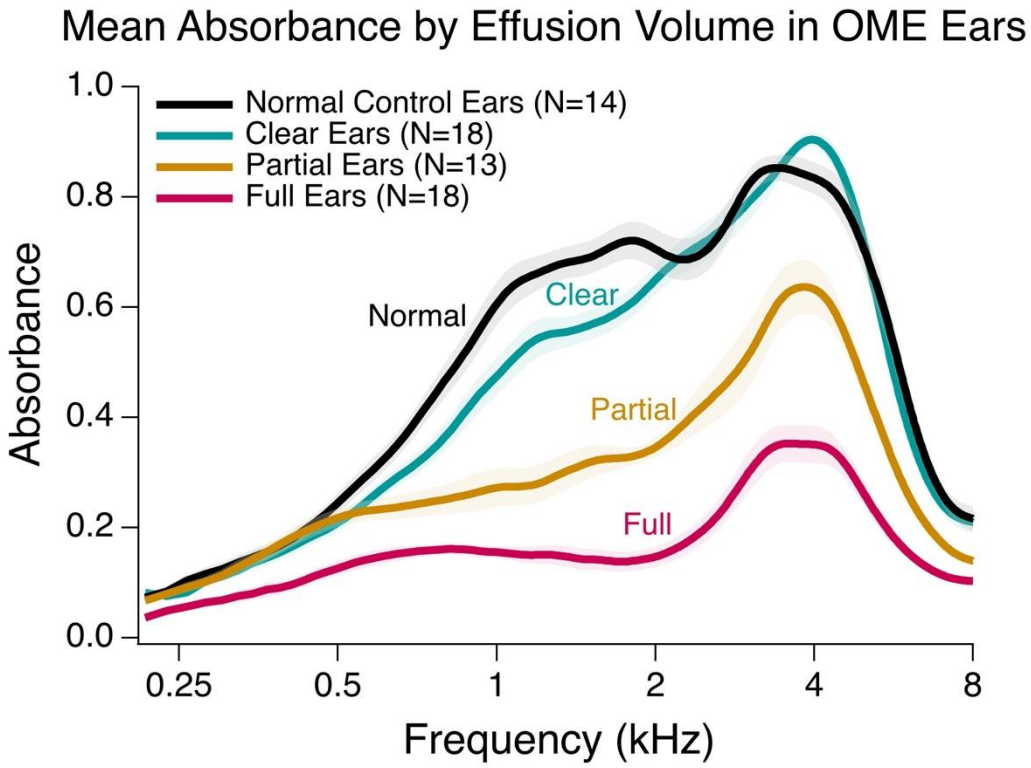


Normal

Clear/Empty

Partial Effusion

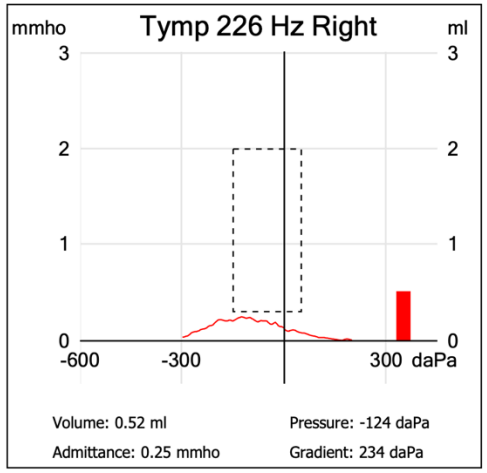
Full Effusion

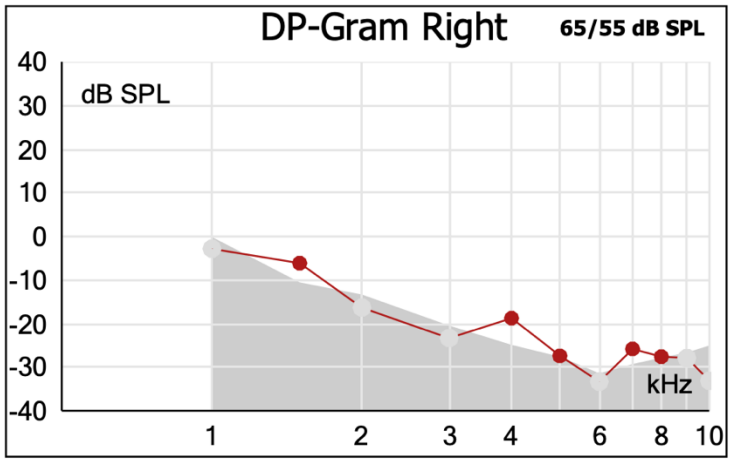


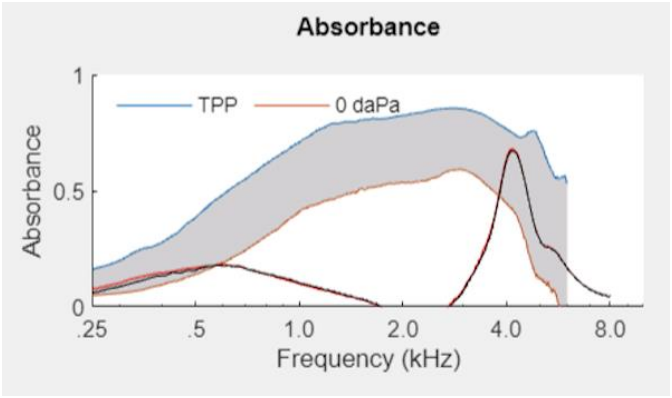
- Wide range of HL for OME. Knowledge of HL is important for management (and likely long-term behavioral outcomes). But testing hearing is hard in this age range!

WBT allows us to infer how a child with OME is hearing, even in cases where behavioral findings are unavailable!

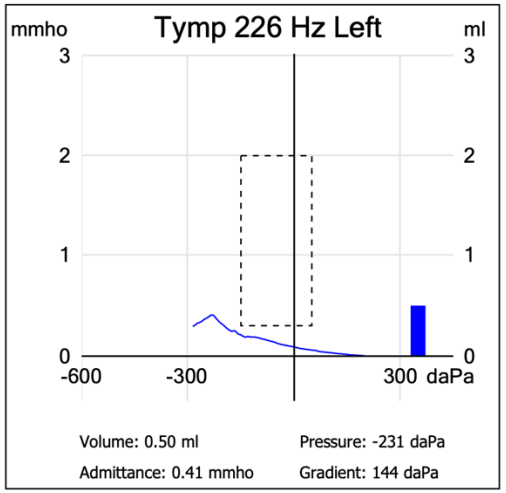
WBT vs Tympanometry

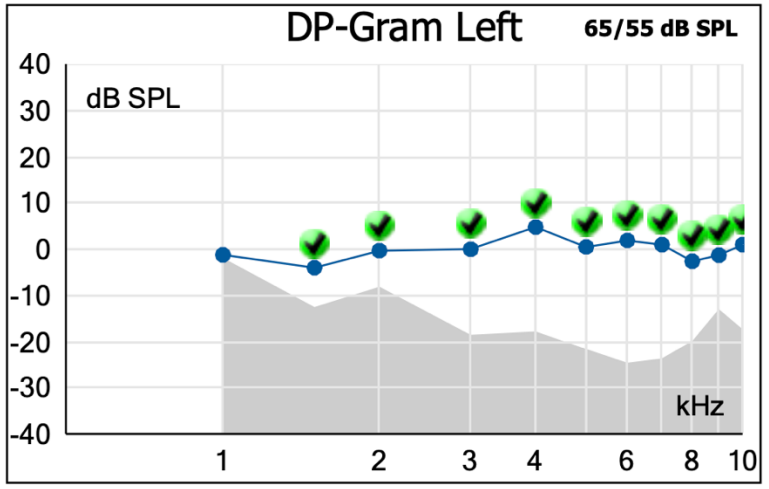


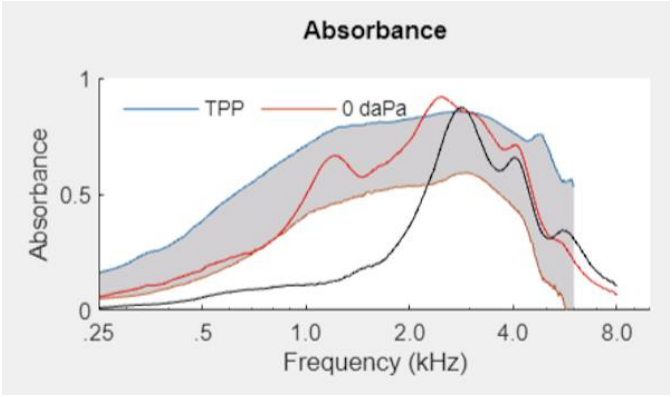




Right: Full effusion/AOM, likely mild to moderate HL





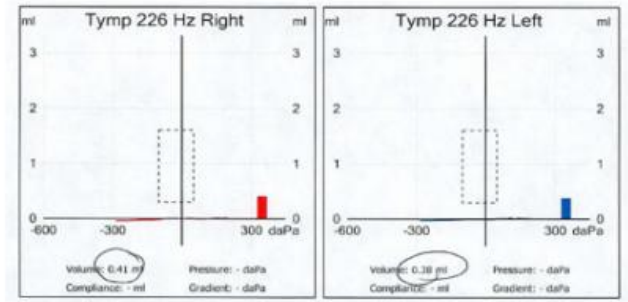


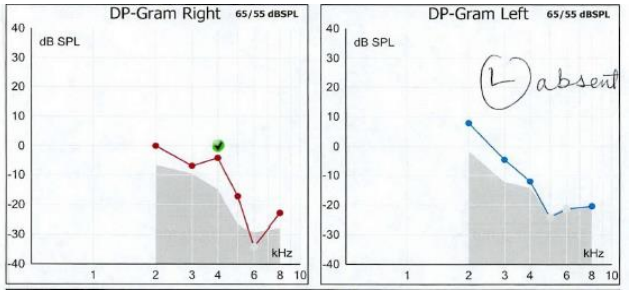
Left: Likely little to no effusion, just negative pressure, normal to near normal hearing

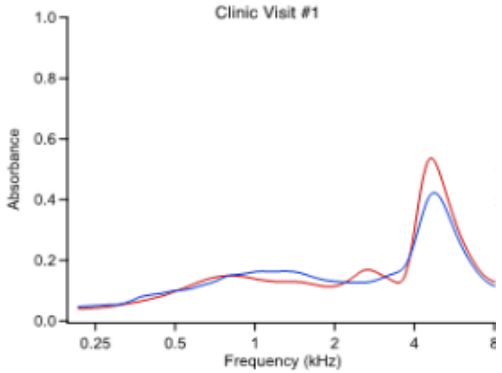
BOYS TOWN
National Research
Hospital

WBT vs Tympanometry

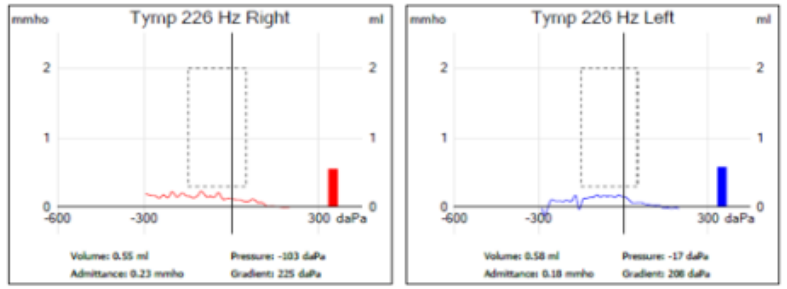
Visit #1

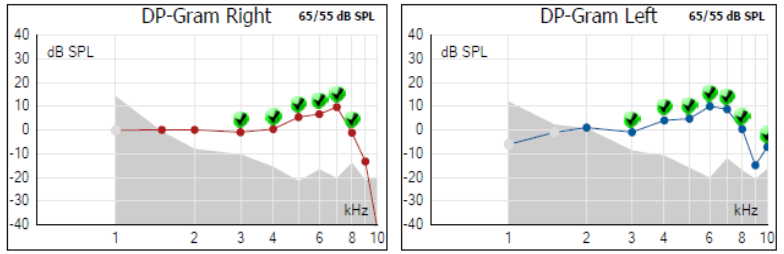


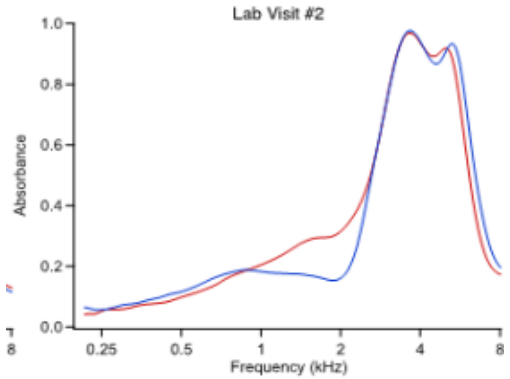




Visit #2

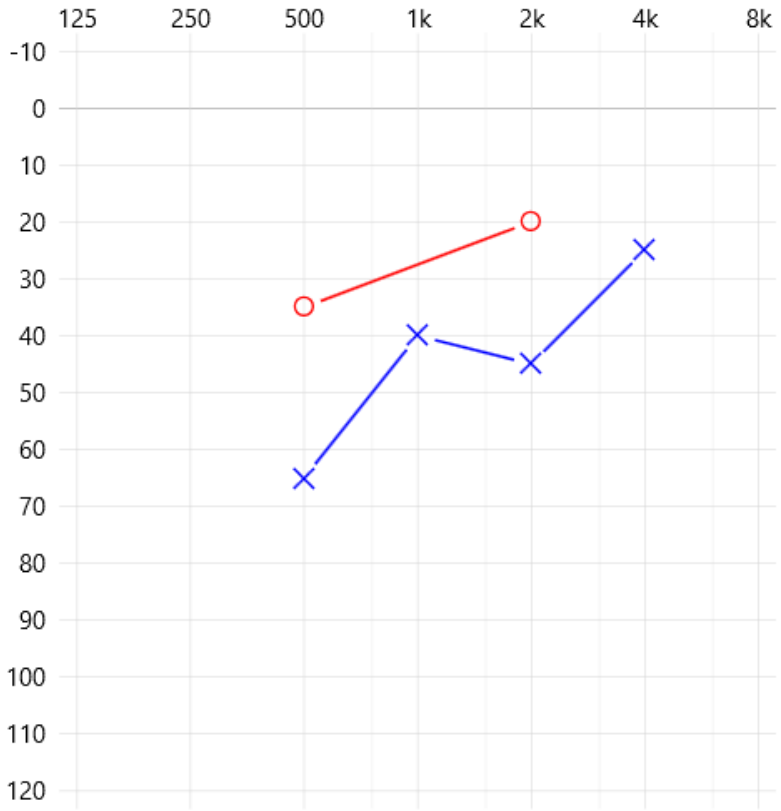


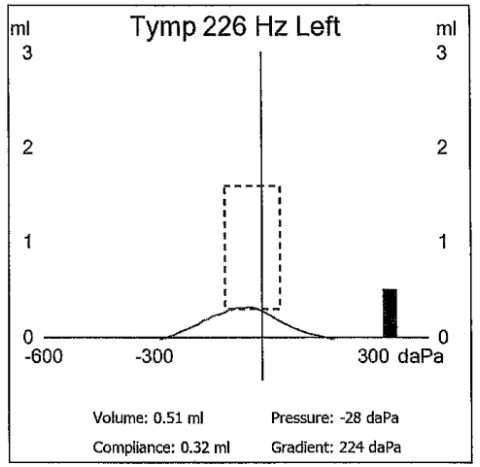


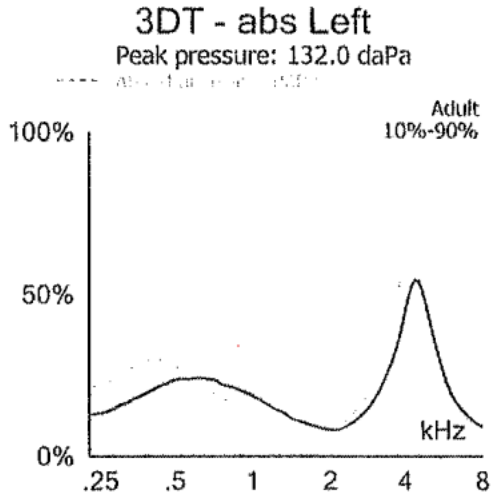


BOYS TOWN National Research Hospital

WBT vs Tympanometry

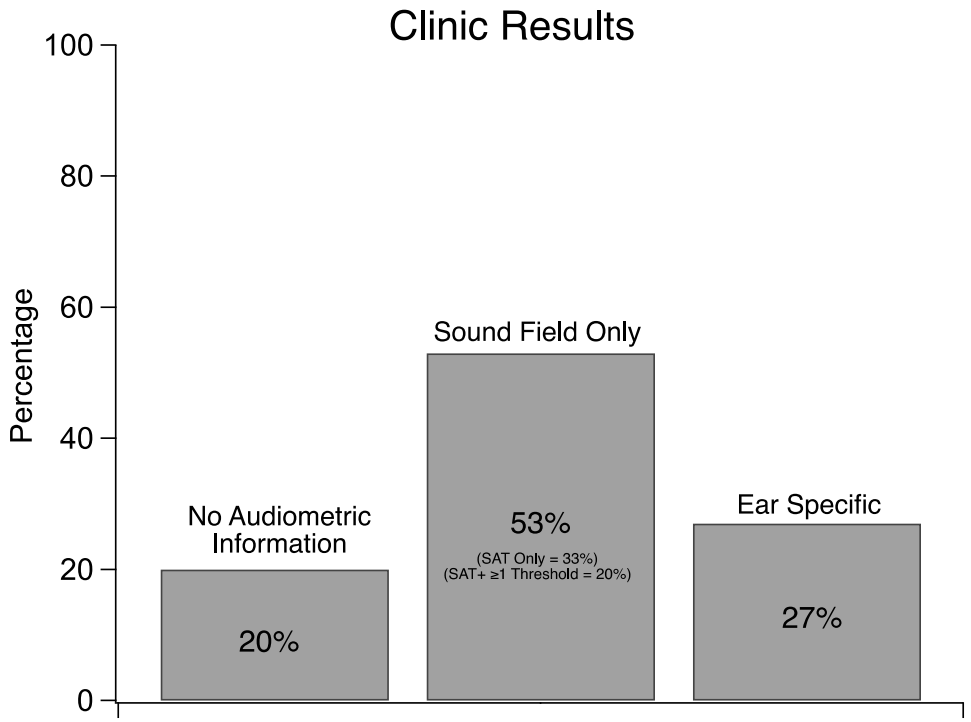






BOYS TOWN
National Research
Hospital

Is audiometric assessment of children with OME challenging? Yes! Especially for ear specific information, even in an ideal research setting.



	Ear Specific Audiometric Test Success					
Visit	***n***	***Age (months)***	**No Ear Specific Information**	**SAT Only**	**≥ 1 Air Threshold**	**≥ 4 Air Thresholds**
Clinic	80	23	73%	4%	23%	15%
Research	80	23	55%	0%	45%	34%

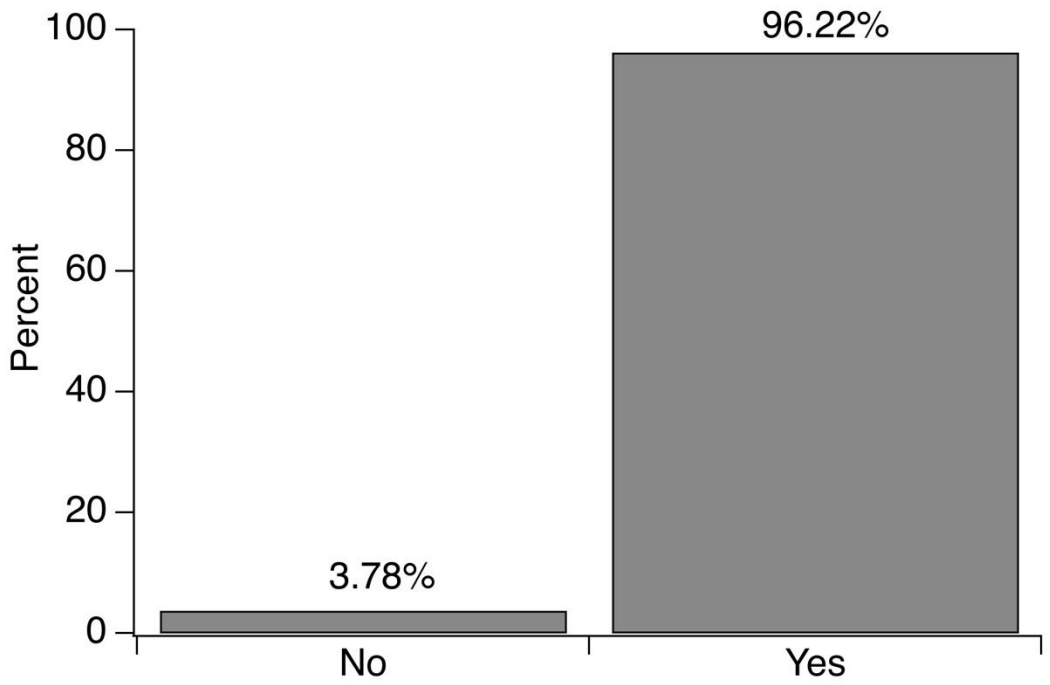
While sound field data is certainly very useful clinically, ear specific information may be particularly important in this population because:

1. OME status in one ear is not well correlated with the contralateral ear.
2. Sound field data could miss a hearing loss in one ear.
3. Deficits in processes like binaural hearing are likely influenced by how both ears are hearing.

Merchant et al., 2024

BOYS TOWN National Research Hospital

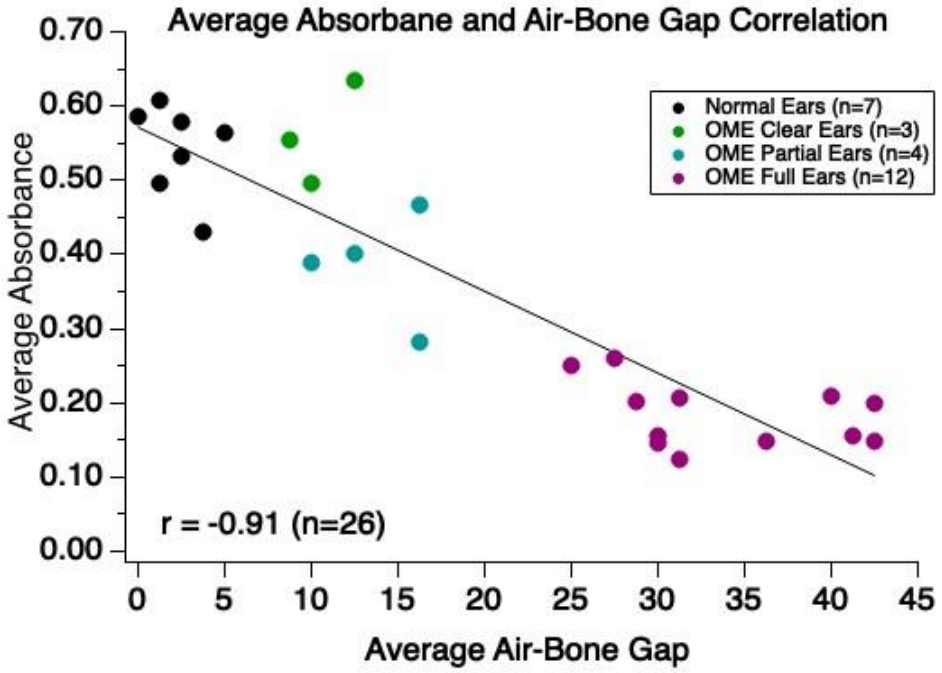
Is WBT Easier? (Yes! Much!)

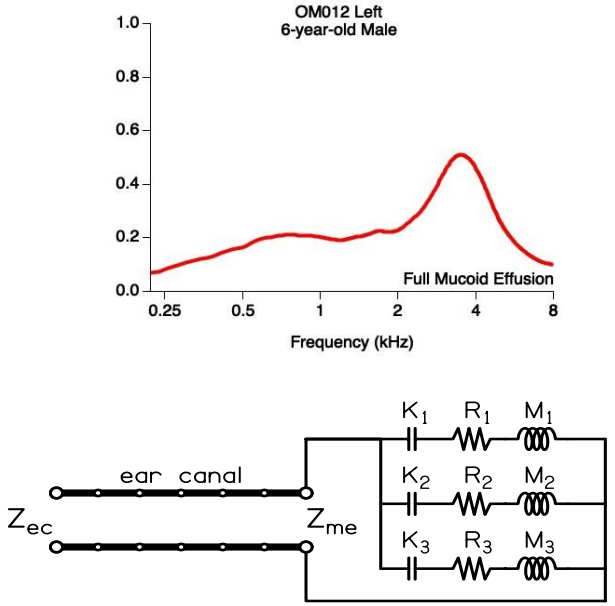


Merchant et al., 2024

BOYS TOWN
National Research
Hospital

In Progress…Directly estimating CHL from WBT

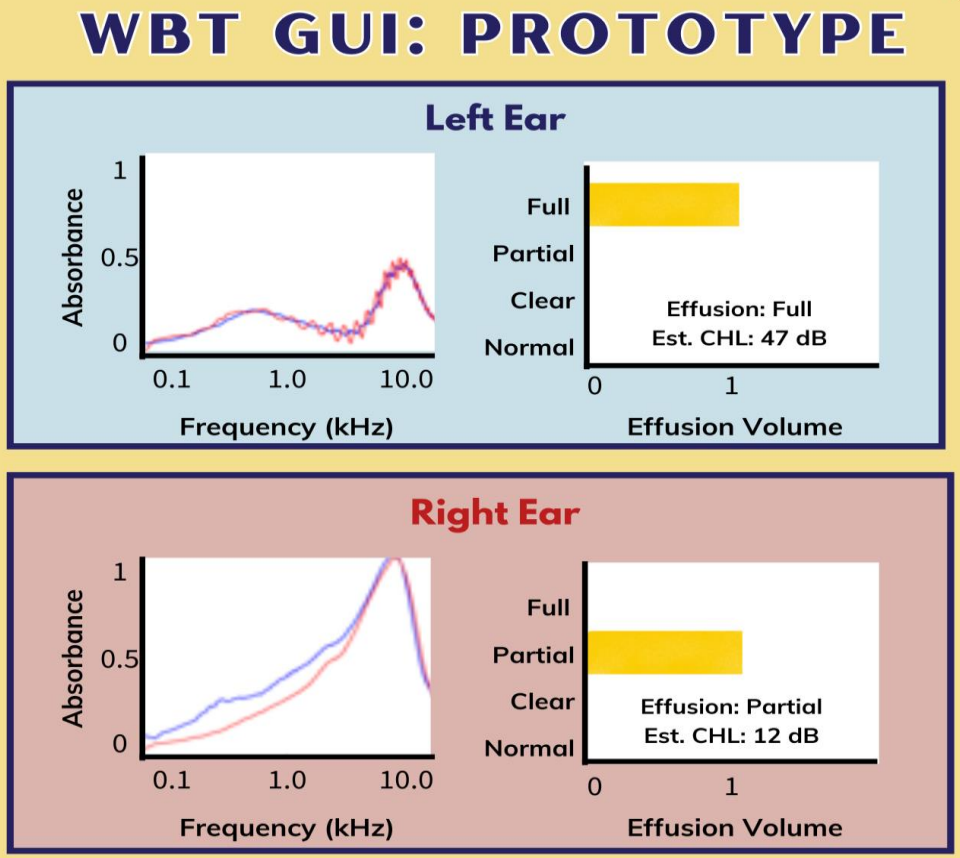




- What if instead of estimating volume from WBT to infer something about hearing, we could directly estimate CHL from an individual WBT Absorbance tracing?
- Goal: Develop a WBT-based acoustic estimate of the CHL caused by OM within 3-5 dB HL. Preliminary data suggests that this is achievable by combining WBT with computational modeling.

Merchant & Neely, 2023

BOYS TOWN National Research Hospital



Future Directions

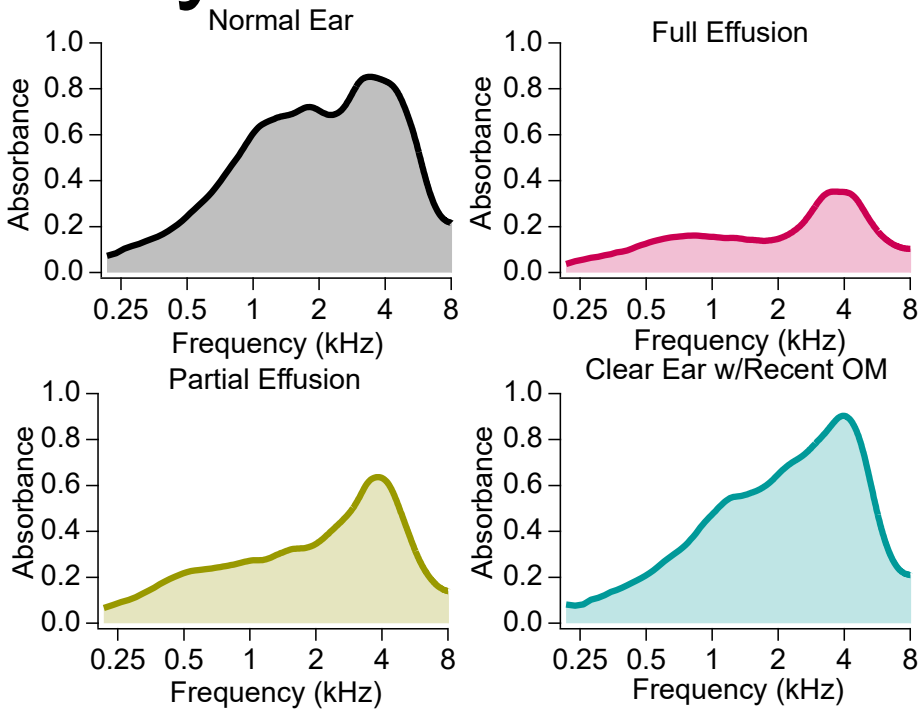
- Develop a machine learning algorithm (based on Merchant & Neely, 2023) to characterize middle-ear effusion volume and estimated hearing thresholds based on WBT findings.
- This tool will make interpretation of WBT findings in children with OME simpler and more efficient!

US Patent App.
US20230240562A1

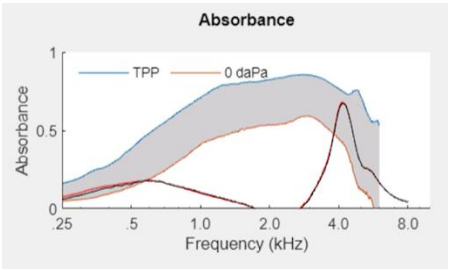
BOYS TOWN National Research Hospital

WBT Interpretation for Peds ME Dysfunction

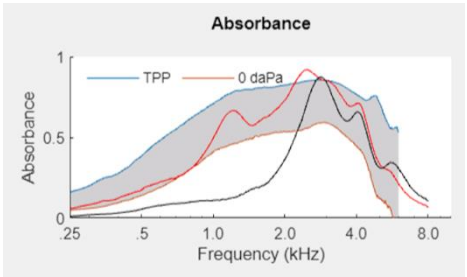
- Until a machine learning interpretation application is available, what can help us with interpretation now?
- Think about area/space below the curve
  - Larger area under the curve = more air in the middle ear = better hearing
  - Even partial effusion will often cause only borderline normal hearing or slight/minimal hearing loss



- If the **ambient/0 daPa** tracing is reduced (black), but the **pressurized** TPP tracing is more normal (red), the reduction is likely due to negative pressure and not (at least not completely) due to fluid
  - <u>TPP tracing will be most useful when it comes to fluid</u>



Fluid



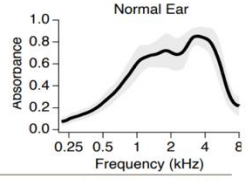
Negative Pressure

BOYS TOWN National Research Hospital

WBT INTERPRETATION GUIDE

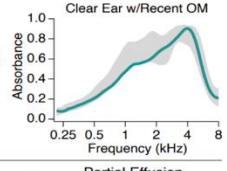
Normal Middle Ear Status

Wideband absorbance is within normal limits across the frequency range, suggesting normal middle-ear function.



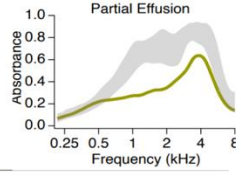
Clear Ear with Recent OME

Wideband absorbance is slightly reduced in the low frequency range, rising to normal limits in the mid and high frequencies.



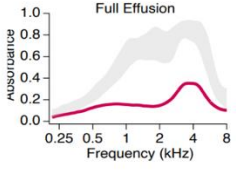
Partial Effusion

Wideband absorbance is partly reduced across the frequency range, suggesting that the middle-ear space is partially filled with fluid.



Full Effusion

Wideband absorbance is largely reduced across the frequency range, suggesting that the middle-ear space is fully filled with fluid.



Clinical Smart Phrases

(Part I)

WBT Testing

General Explanation

Wideband tympanometry (WBT) testing was completed today. This test utilizes a broadband click stimulus to measure how effectively sound is transmitted through the middle-ear system. WBT absorbance refers to the amount of sound energy that is absorbed by the middle ear across frequencies.

WBT Absorbance

Use for Suspected Cases of OME in Children

WBT absorbance measurements can be used to predict the volume of middle-ear effusion with high sensitivity and estimate the amount of transient conductive hearing loss that likely coincides with a given episode of OME.

WBT Results - OME

Full Effusion

WBT absorbance is largely reduced across most frequencies, with a slight peak noted between 4-6 kHz. Findings indicate that the middle-ear space is fully filled with fluid, likely causing a mild-moderate degree of transient conductive hearing loss.

Partial Effusion

WBT absorbance is partially, but not completely, reduced across the frequency range, suggesting that the middle-ear space is partially filled with fluid. Partial effusions are generally consistent with a slight transient conductive hearing loss and/or normal hearing sensitivity.

Clear Ear with Recent OME

WBT absorbance is slightly reduced in the low frequency range, rising to normal limits in the mid and high frequencies. This finding is suggestive of a clear middle-ear space with a recent history of OME, with hearing sensitivity ranging from borderline normal to normal limits. Various factors may contribute to a decreased low-frequency absorbance, such as possible inflammation.

Contact Us

Email: TAPP.Lab@boystown.org

'S TOWN
nal Research
Hospital

Scan to Access WBT Resources!

Scan the QR code to view:

- WBT Interpretation Infographic
- WBT Smart Phrases for Clinical Report-Writing

BOYS TOWN National Research Hospital

In Progress…
Monitoring OME & CHL via Mobile Testing

- Improved knowledge of what is happening with a given episode of OME is helpful but may not tell us much about long-term outcomes or cumulative auditory deprivation. Need longitudinal data for that.
- Goal of our Mobile OM (MOM) Project: Understand the trajectory of OME episodes **and prognostic value of WBT (i.e. can we predict which effusions will persist versus which will spontaneously resolve)**
- **Initial Audiologic Assessment Battery**
  - Otoscopy
  - 226 Hz Tympanometry
  - Wideband Acoustic Immittance
  - Distortion Product Otoacoustic Emissions (DPOAEs): 1-10 kHz
  - Behavioral Pure-Tone Audiometry
- **Weekly Monitoring Assessment**
  - Otoscopy
  - 226 Hz Tympanometry
  - Wideband Acoustic Immittance
  - Distortion Product Otoacoustic Emissions (DPOAEs): 1-10 kHz

BOYS TOWN National Research Hospital

Mobile Testing for OME Monitoring

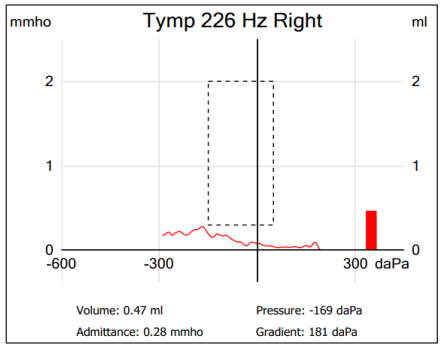
BOYS TOWN
National Research
Hospital

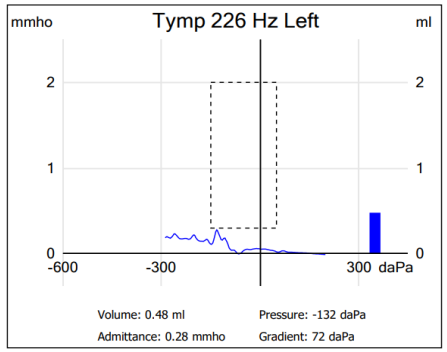
Mobile OME Monitoring

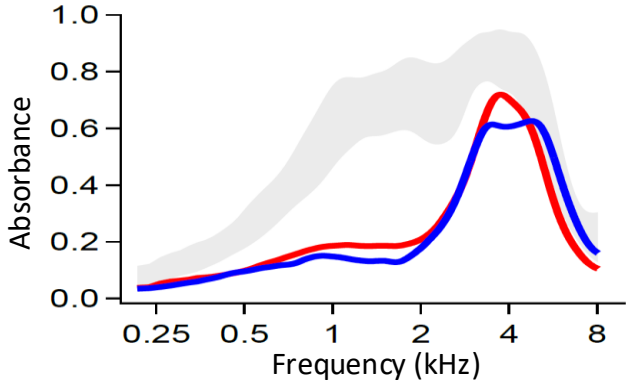
TRANSLATIONAL AUDITORY PHYSIOLOGY & PERCEPTION LAB
Mobile Otitis Media

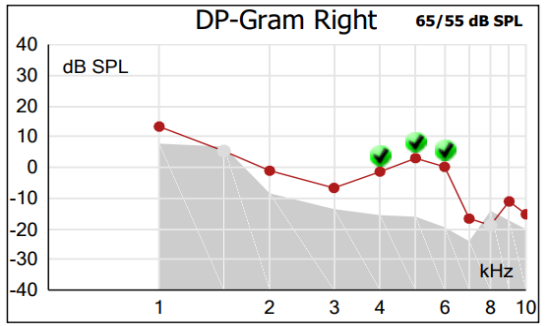
BOYS TOWN National Research Hospital

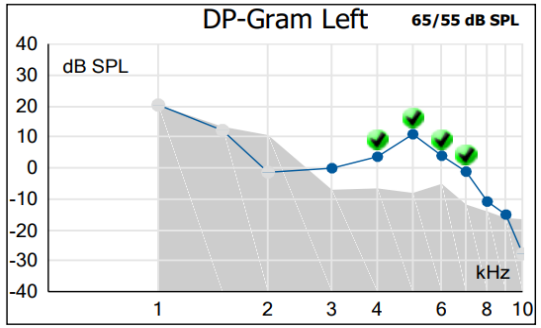
Case Study 1 – Initial Visit











Impressions:

Left Ear

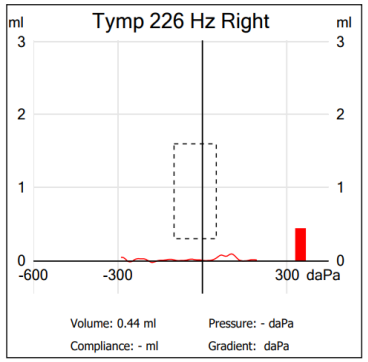
- Tympanometry - Abnormal
- WBT – Partial effusion
- Partially present DPOAEs

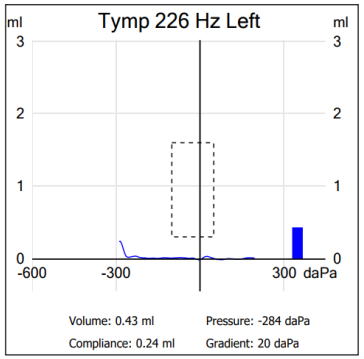
Right Ear

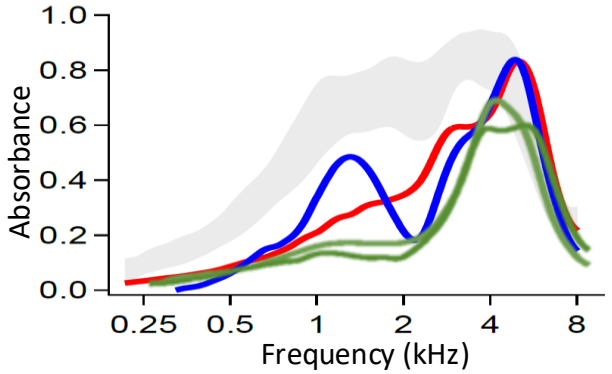
- Tympanometry - Abnormal
- WBT – Partial effusion
- Partially present DPOAEs

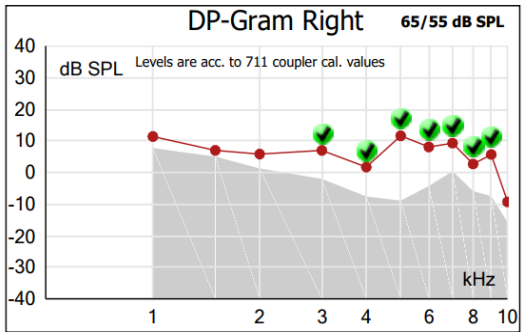
BOYS TOWN National Research Hospital

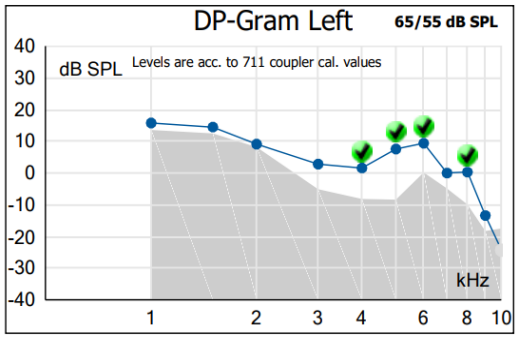
Case Study 1 – Second Visit (~1 week later)











Impressions:

Left Ear

- Tympanometry - Abnormal
- WBT – Partial effusion
- Partially present DPOAEs

Right Ear

- Tympanometry - Abnormal
- WBT – Partial effusion
- Partially present DPOAEs

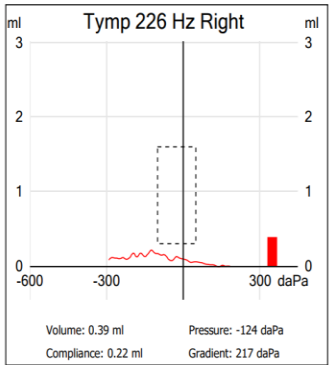
= Left Ear

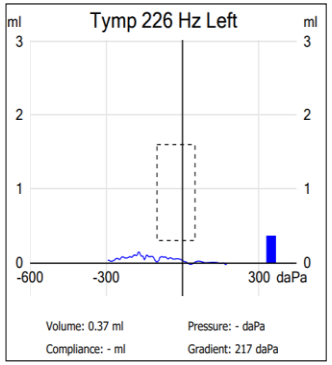
= Right Ear

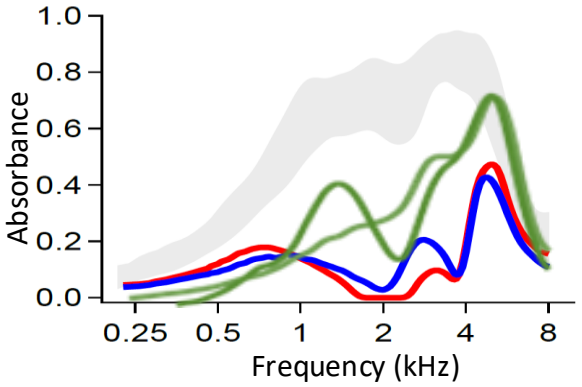
= Right & Left Ear Previous

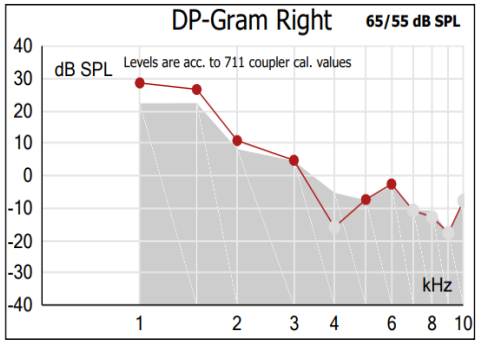
BOYS TOWN National Research Hospital

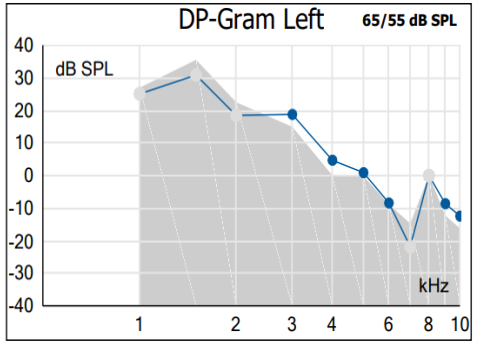
Case Study 1 – Third Visit (~3 weeks later)











Impressions:

Left Ear	Right Ear
• Tympanometry - Abnormal	• Tympanometry - Abnormal
• WBT – Full effusion	• WBT – Full effusion
• Absent DPOAEs	• Absent DPOAEs

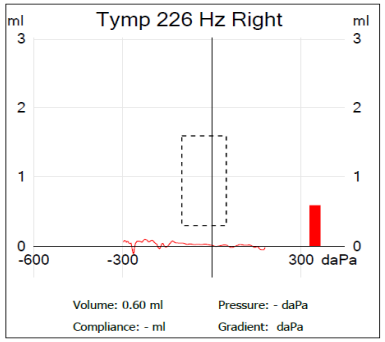
= Left Ear

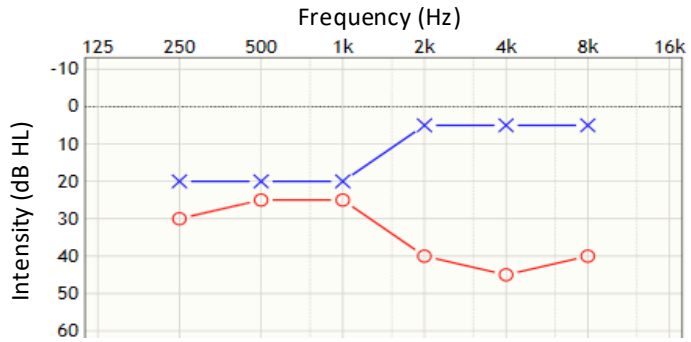
= Right Ear

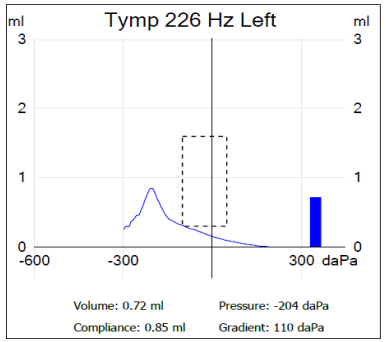
= Right & Left Ear Previous

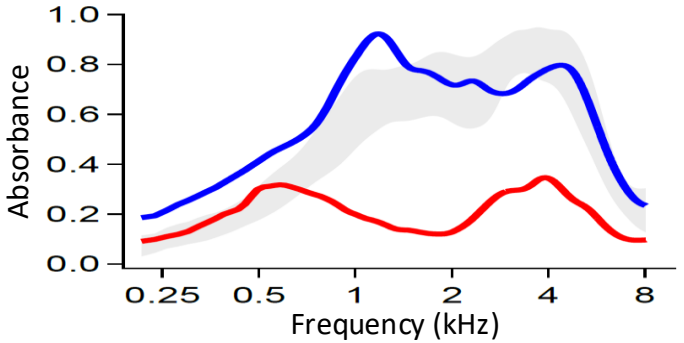
BOYS TOWN National Research Hospital

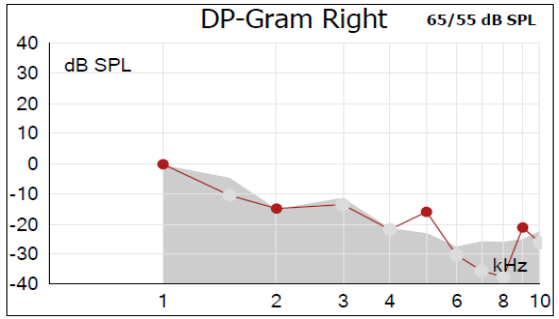
Case Study 2 – Initial Visit

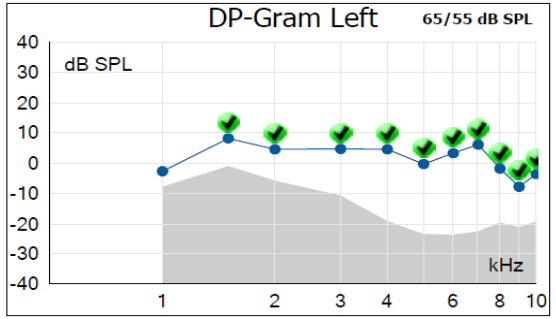












Impressions:

Left Ear

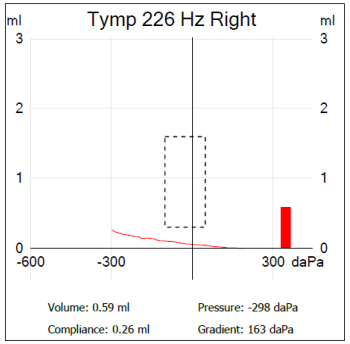
- Tympanometry - Abnormal
- WBT – Clear middle-ear space; WNL
- Normal hearing sensitivity
- Mostly present DPOAEs

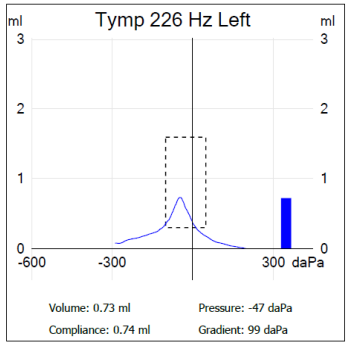
Right Ear

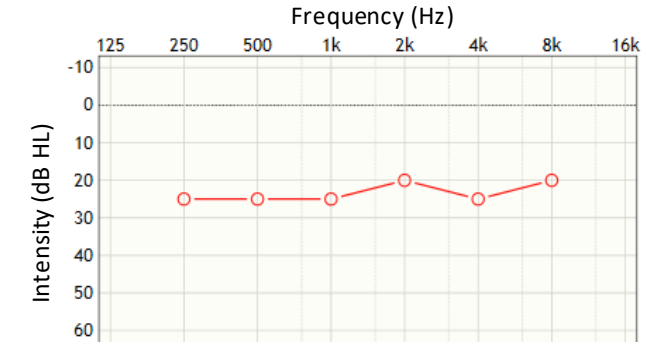
- Tympanometry - Abnormal
- WBT – Full effusion
- Mild to moderate conductive hearing loss
- Absent DPOAEs

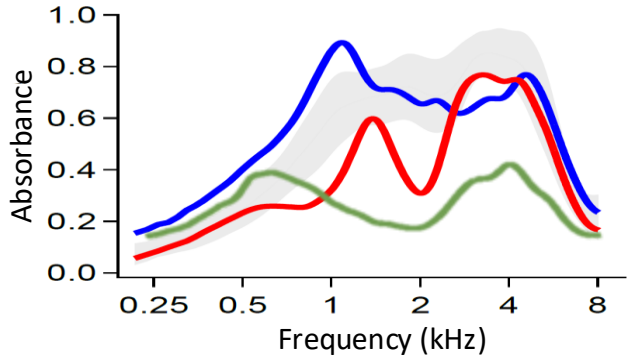
BOYS TOWN National Research Hospital

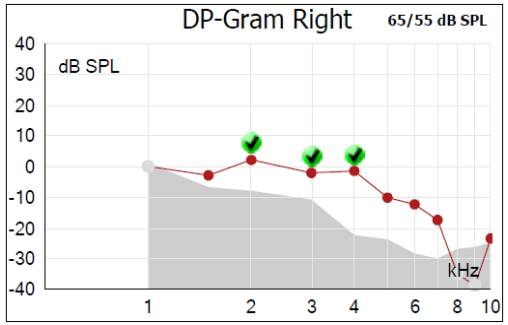
Case Study 2 – Second Visit (~1 week later)

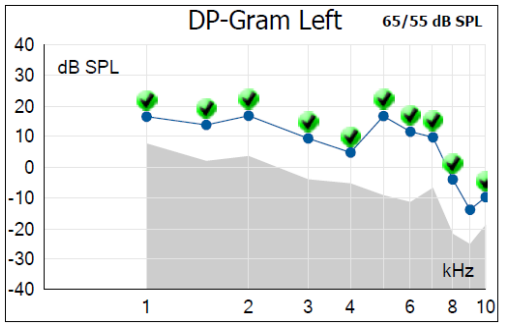












Impressions:

Left Ear

- Stable as compared to initial visit
- Middle-ear function and hearing sensitivity are WNL

Right Ear

- Tympanometry - Abnormal
- WBT – Partial effusion
- Mild conductive hearing loss to borderline normal hearing
- Partially present DPOAEs

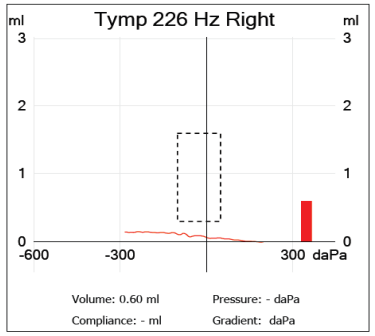
= Left Ear

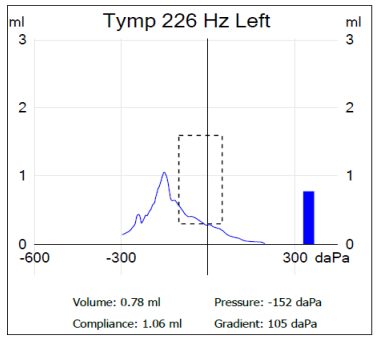
= Right Ear

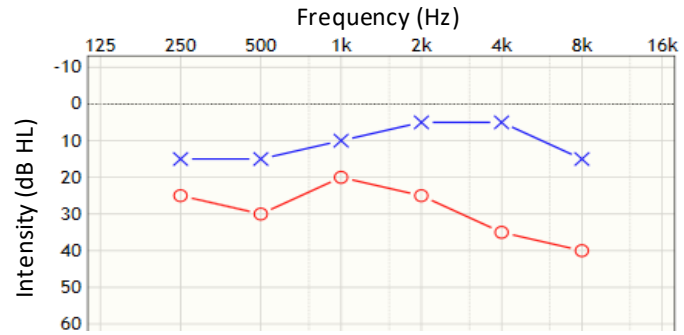
= Right Ear Previous

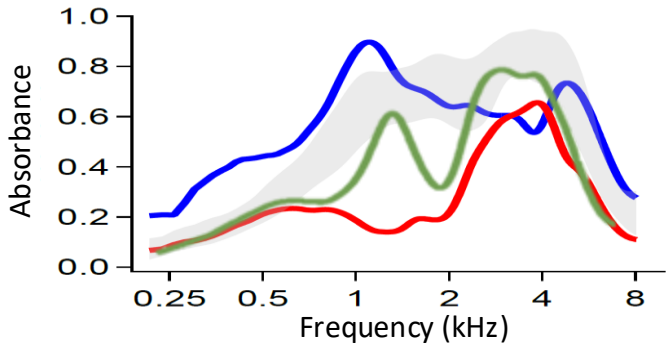
BOYS TOWN National Research Hospital

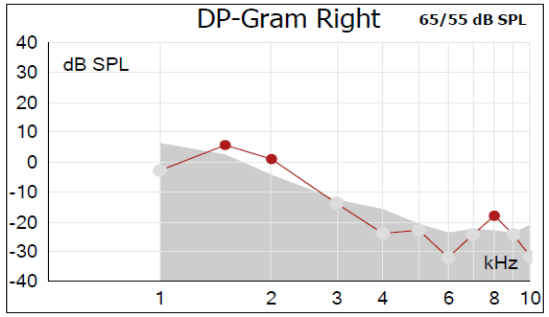
Case Study 2 – Third Visit (~1 week later)

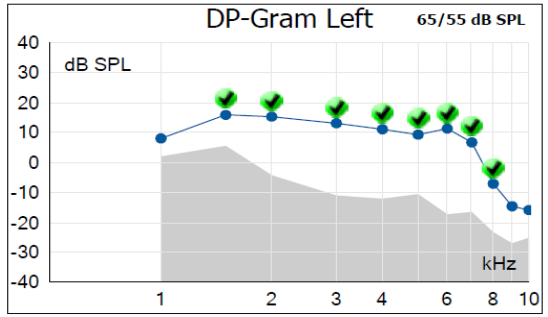












Impressions:

Left Ear

- Stable as compared to initial visit
- Middle-ear function and hearing sensitivity are WNL

Right Ear

- Tympanometry - Abnormal
- WBT – Full effusion
- Mild conductive hearing loss
- Absent DPOAEs

= Left Ear

= Right Ear

= Right Ear Previous

BOYS TOWN National Research Hospital

Takeaways

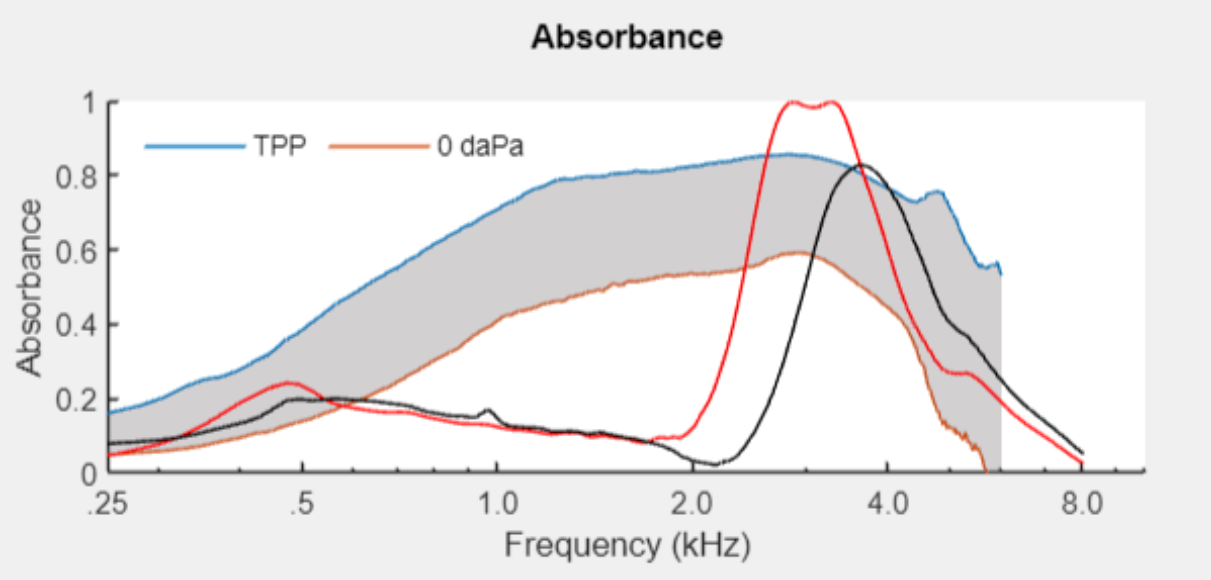
- WBT has immense clinical utility AND is feasible to obtain in clinical settings, even with infants and toddlers.

- WBT absorbance can be used to predict effusion volume and hearing status in children with OME.

- WBT is a valuable tool for monitoring fluctuations in middle-ear function, which can be used to enhance clinical management of OME.

Now let’s test our knowledge… ;)

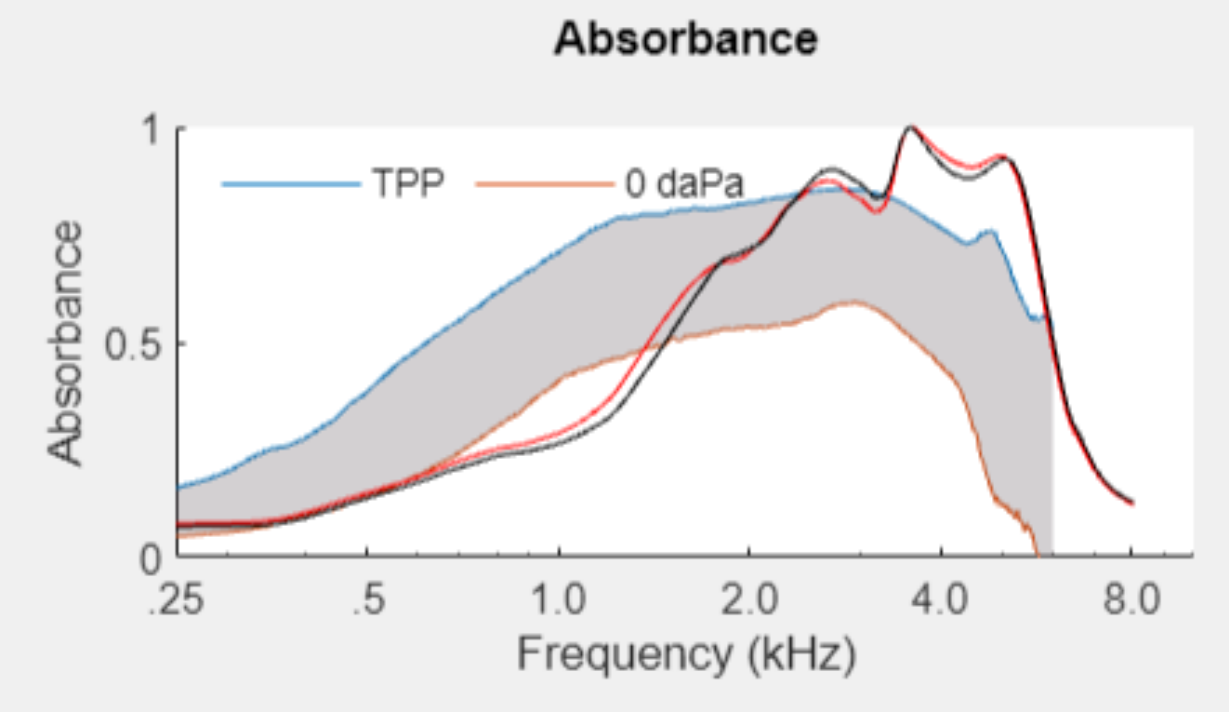
How much fluid/effusion is in this ear?



1. Full Effusion
2. Partial Effusion
3. Clear Ear
4. None of the above

BOYS TOWN National Research Hospital

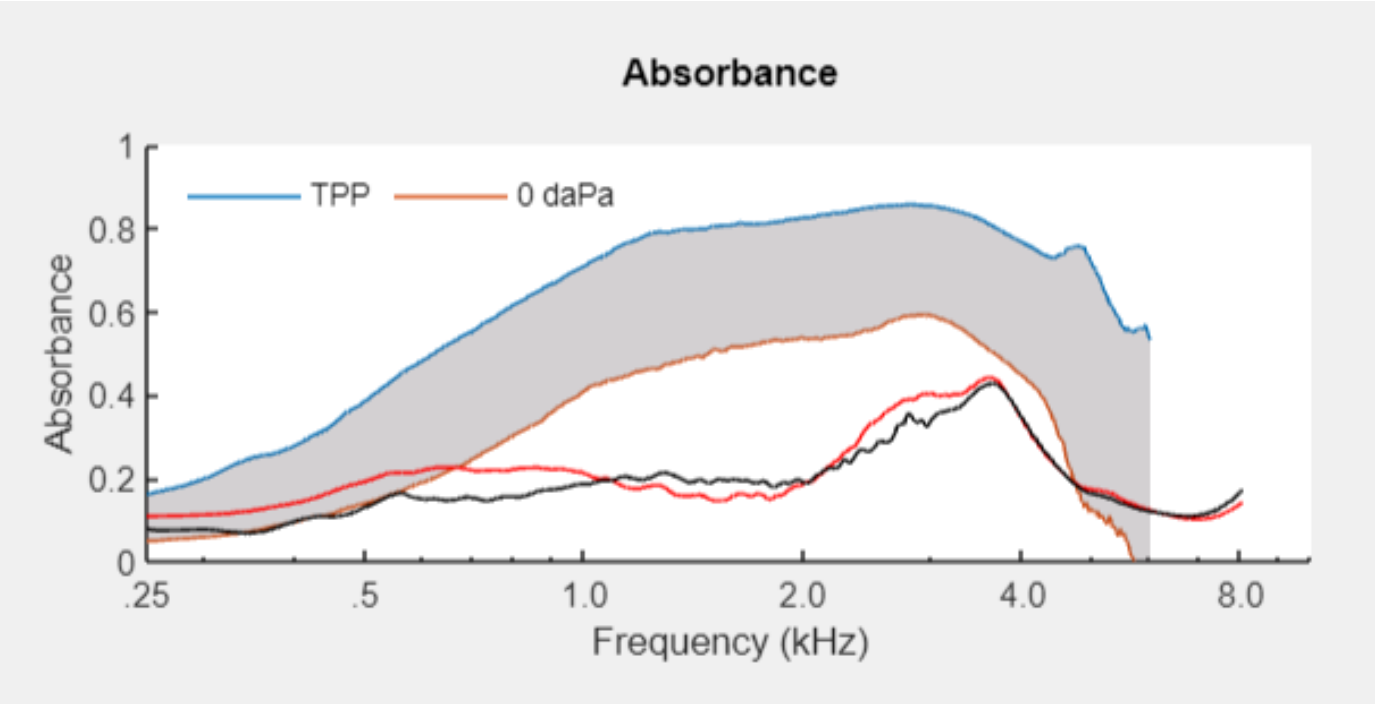
How much fluid/effusion is in this ear?



1. Full Effusion
2. Partial Effusion
3. Clear Ear
4. None of the above

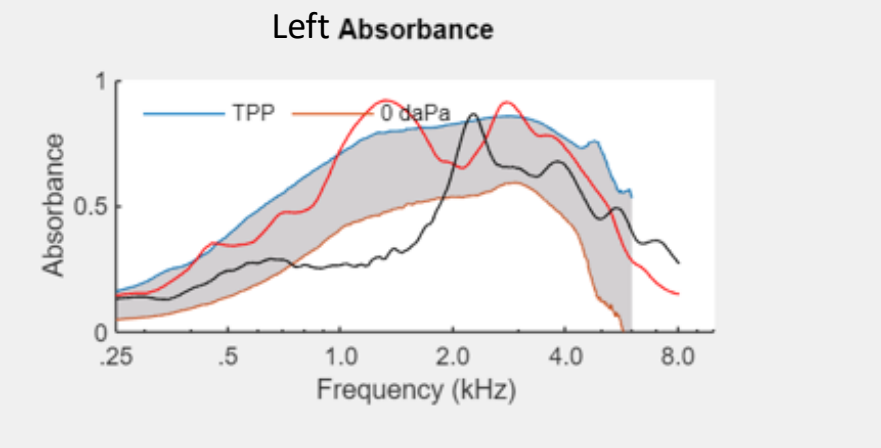
BOYS TOWN National Research Hospital

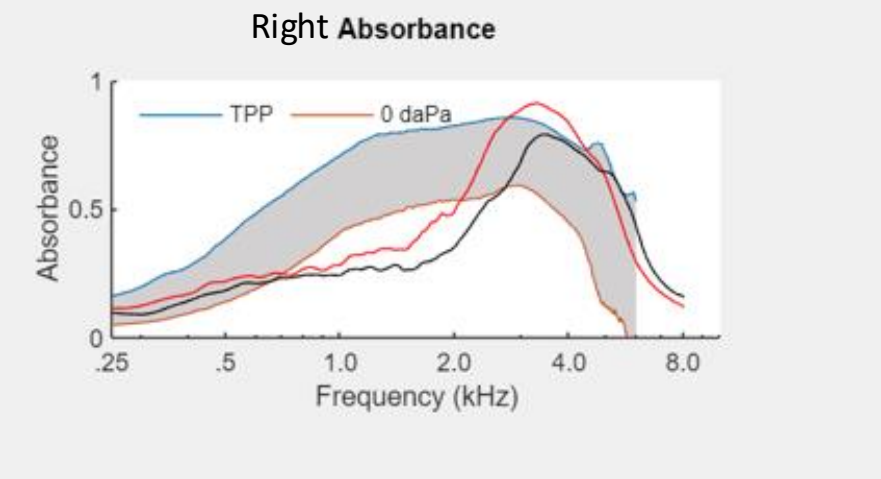
How much fluid/effusion is in this ear?



1. Full Effusion
2. Partial Effusion
3. Clear Ear
4. None of the above

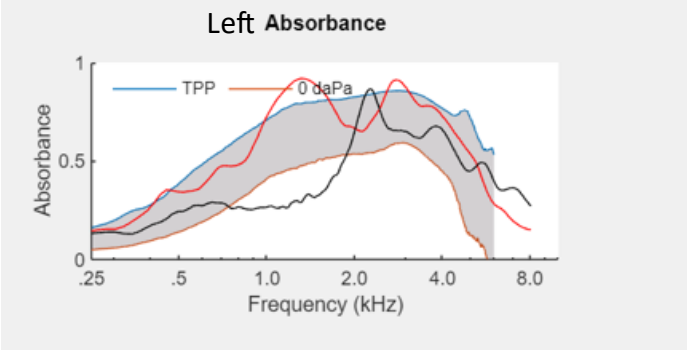
Which ear do you think is hearing better?

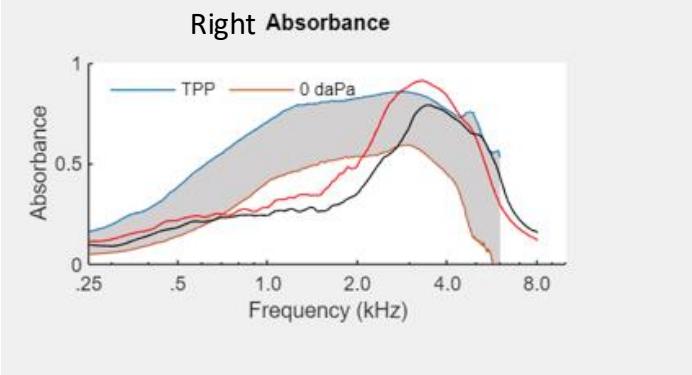


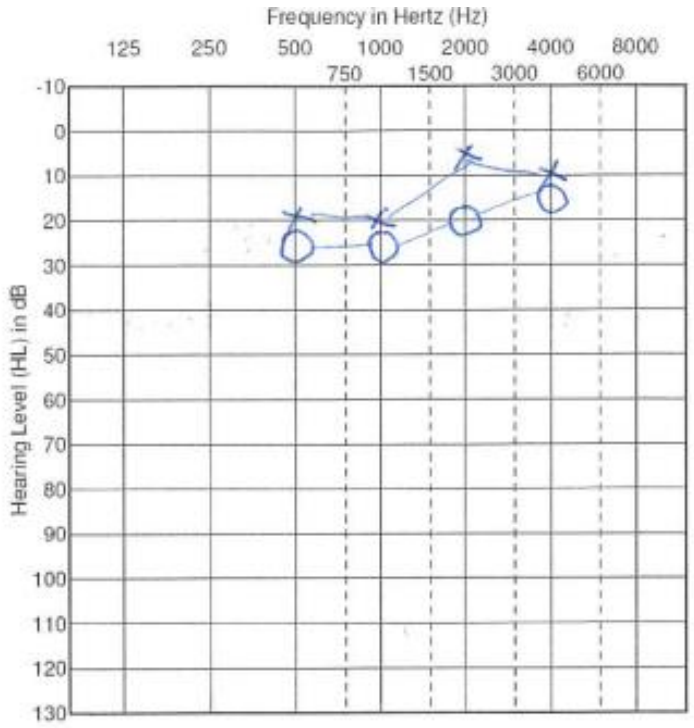


1. Left Ear
2. Right Ear

BOYS TOWN National Research Hospital

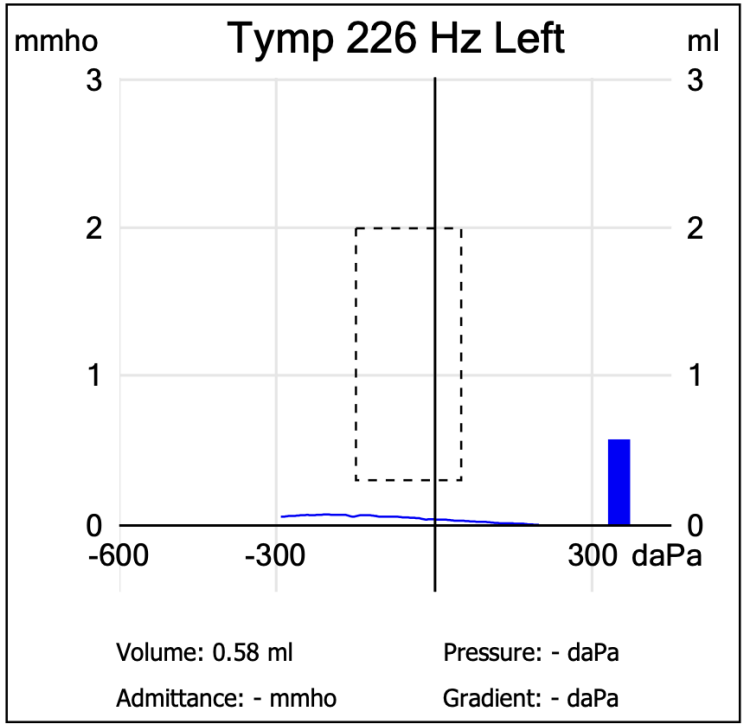






BOYS TOWN
National Research
Hospital

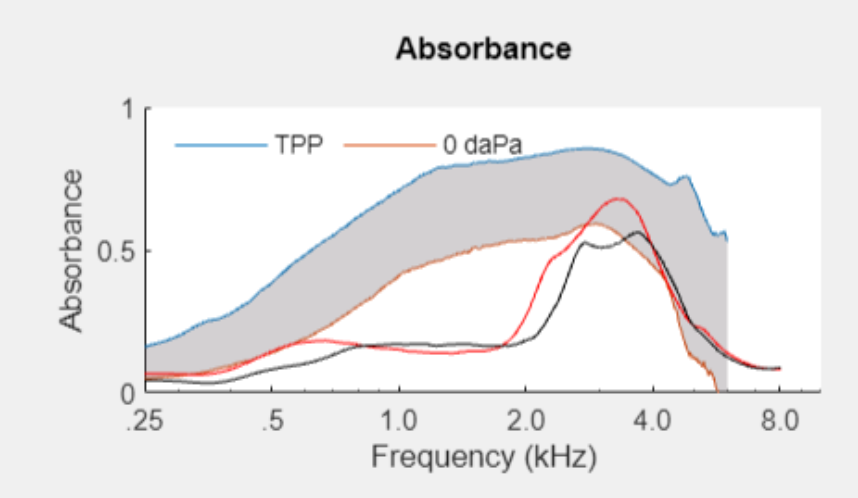
How is this left ear hearing?



1. Normal Hearing
2. Borderline Normal
3. Mild to Moderate Loss
4. I'm not sure based on this

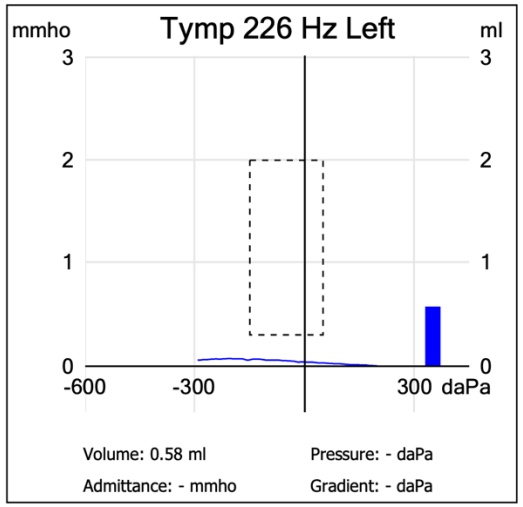
BOYS TOWN National Research Hospital

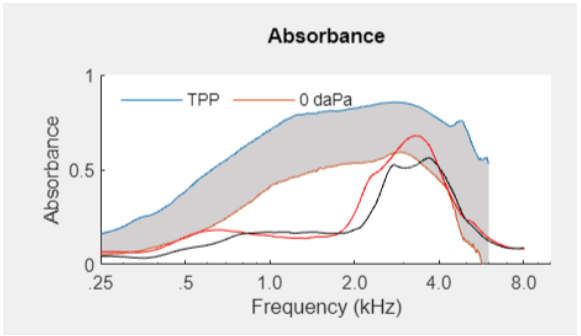
How is this left ear hearing?

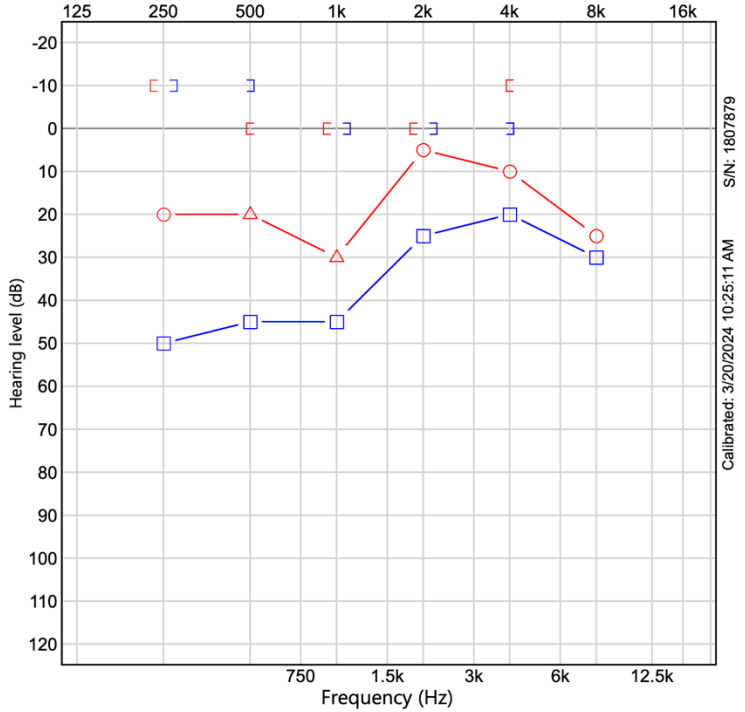


1. Normal Hearing
2. Borderline Normal
3. Mild to Moderate Loss
4. I'm not sure based on this

BOYS TOWN National Research Hospital

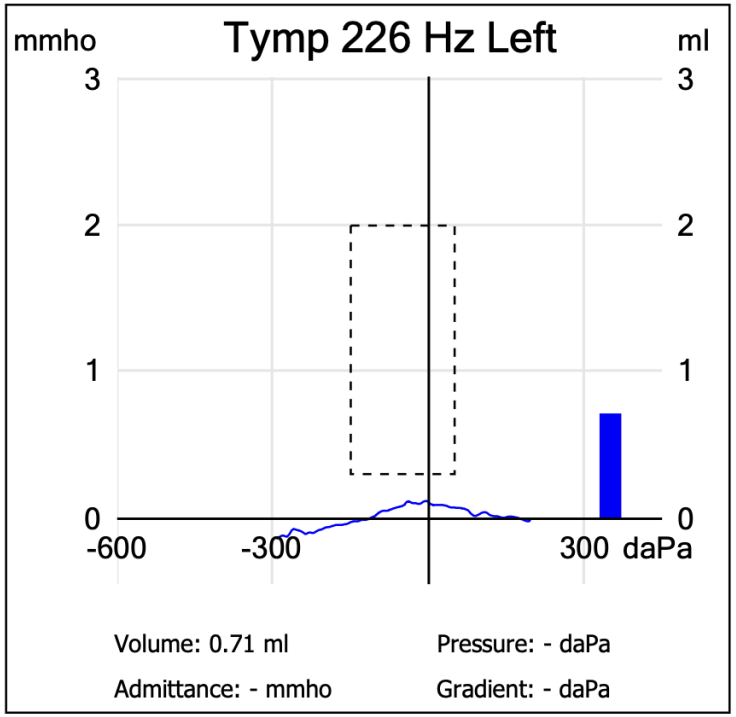






BOYS TOWN
National Research
Hospital

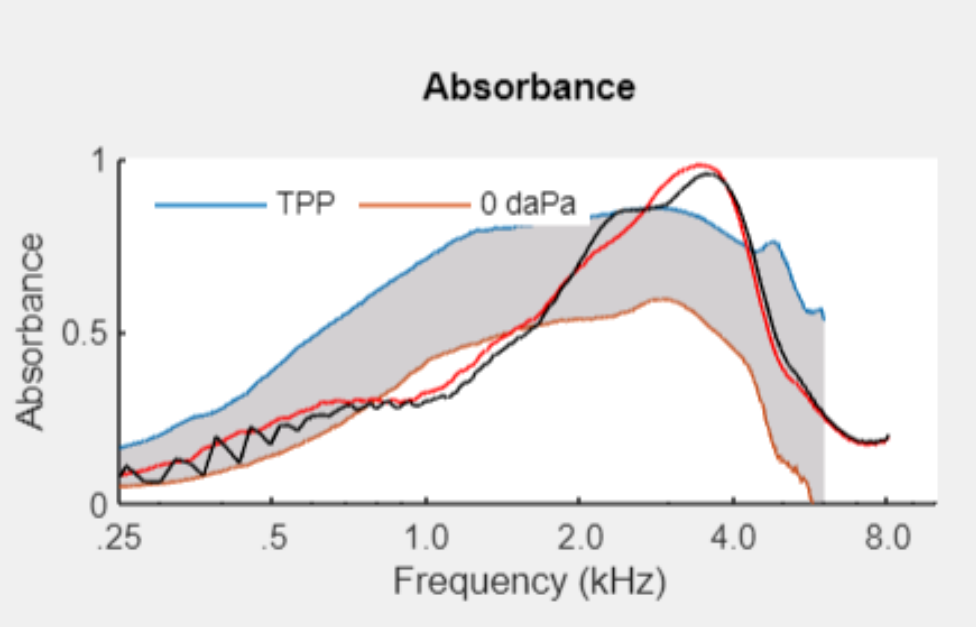
How is this left ear hearing?



1. Normal Hearing
2. Borderline Normal
3. Mild to Moderate Loss
4. I'm not sure based on this

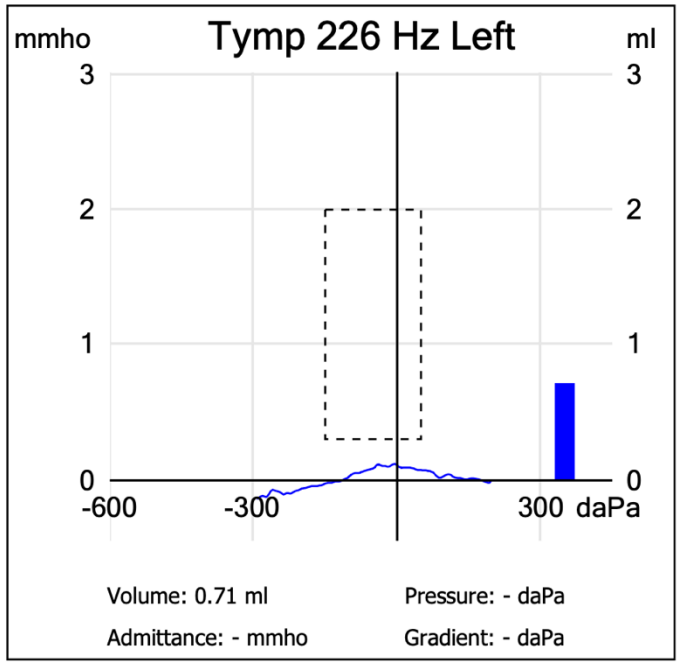
BOYS TOWN National Research Hospital

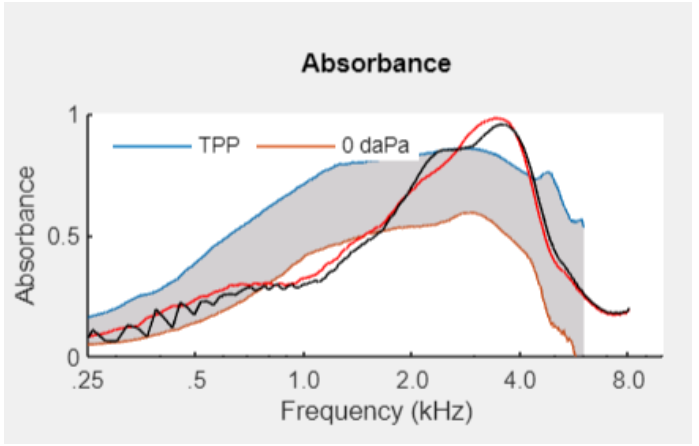
How is this left ear hearing?

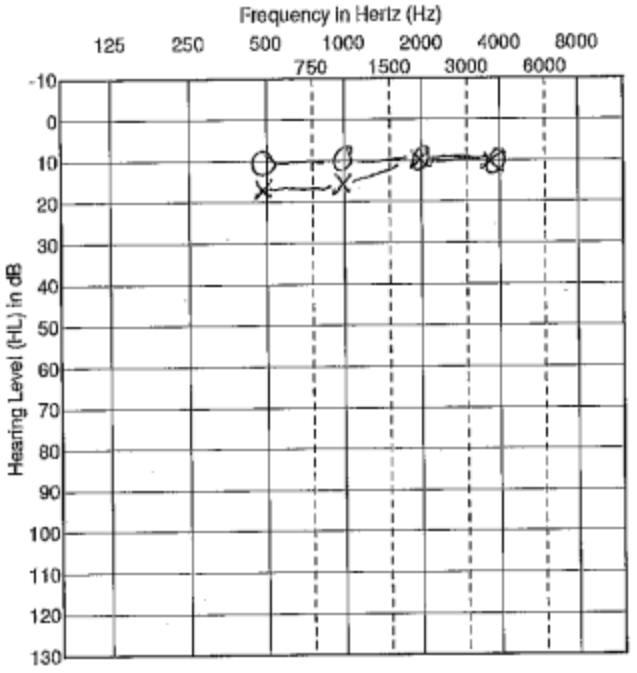


1. Normal Hearing
2. Borderline Normal
3. Mild to Moderate Loss
4. I'm not sure based on this

BOYS TOWN National Research Hospital







BOYS TOWN
National Research
Hospital

Differential Diagnosis of CHL

Differential Diagnosis of CHL Pathology: A Clinical Dilemma

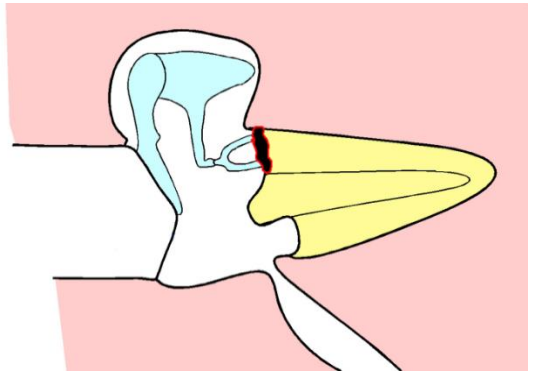
- Patient has CHL on audiogram (defined as air-bone gap)
  - Typically, next step would be to determine cause by physical exam
- Physical exam shows a **healthy, intact tympanic membrane (TM) and a well-aerated middle ear**
  - No fluid, no perforation, no infection

- **What is causing the hearing loss?**

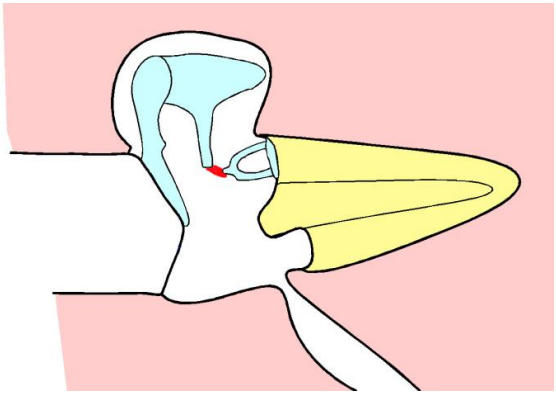
- **How do we differentiate the cause of the CHL??**

Pathologies Resulting in CHL w/Healthy TM & Well-Aerated Middle Ear

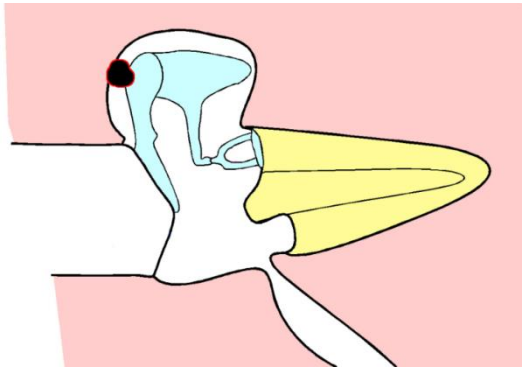
Stapes Fixation



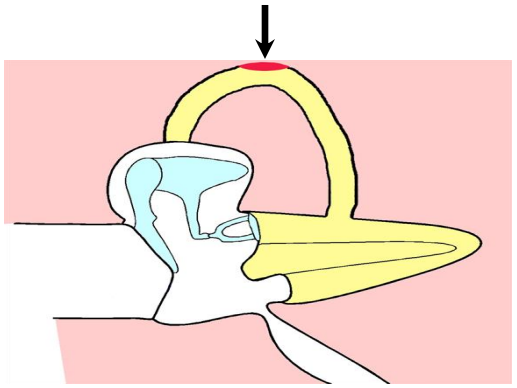
Ossicular Discontinuity



Malleus Fixation

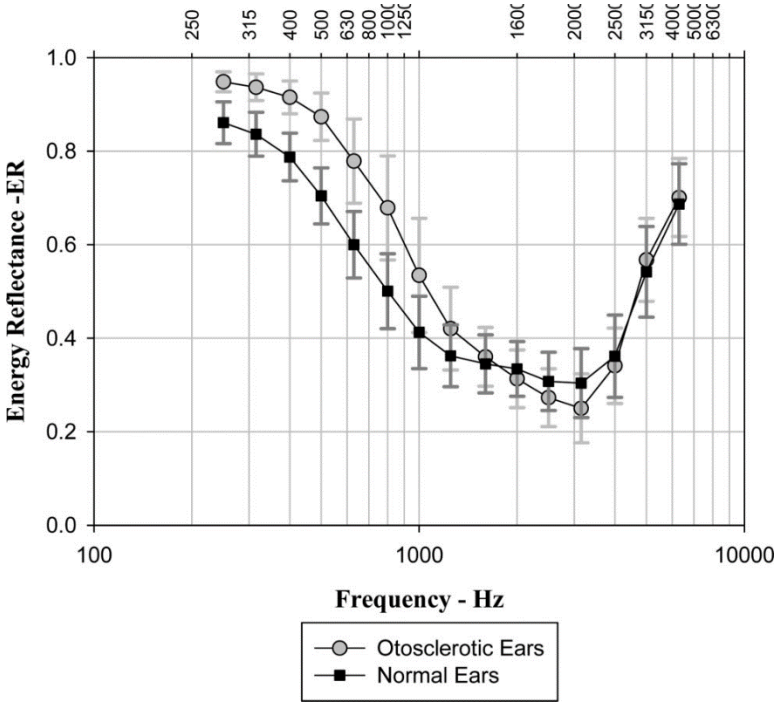


Superior Semicircular Canal Dehiscence

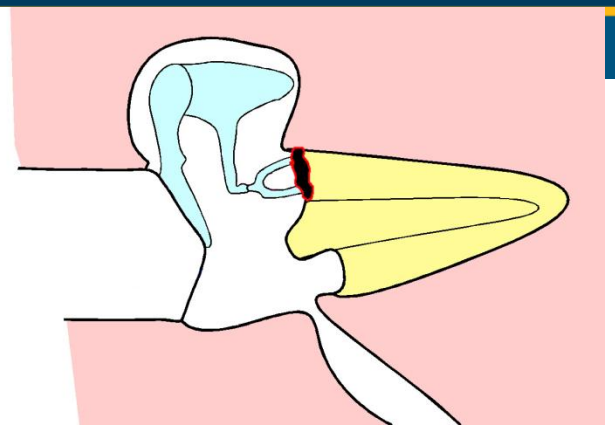


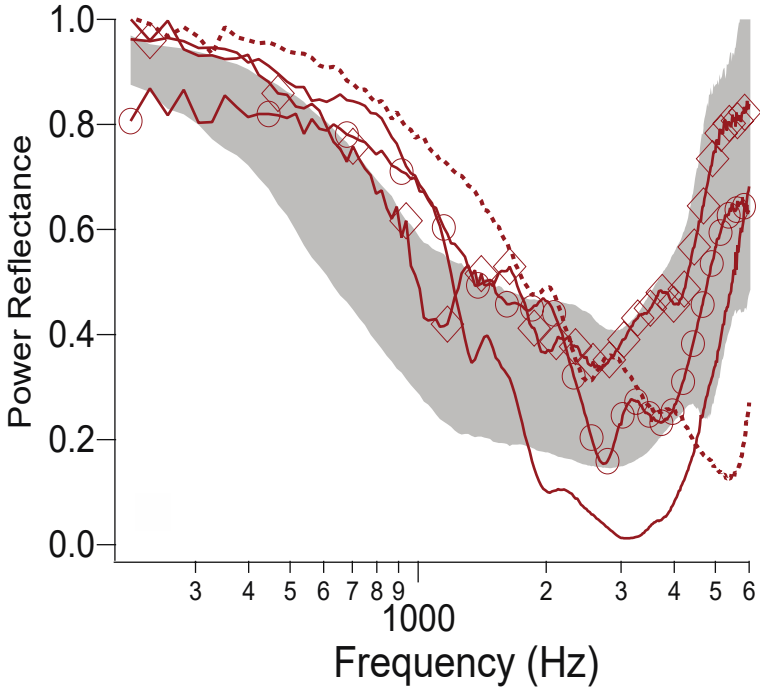
BOYS TOWN National Research Hospital

Fixed Stapes



Shahnaz et al., 2009



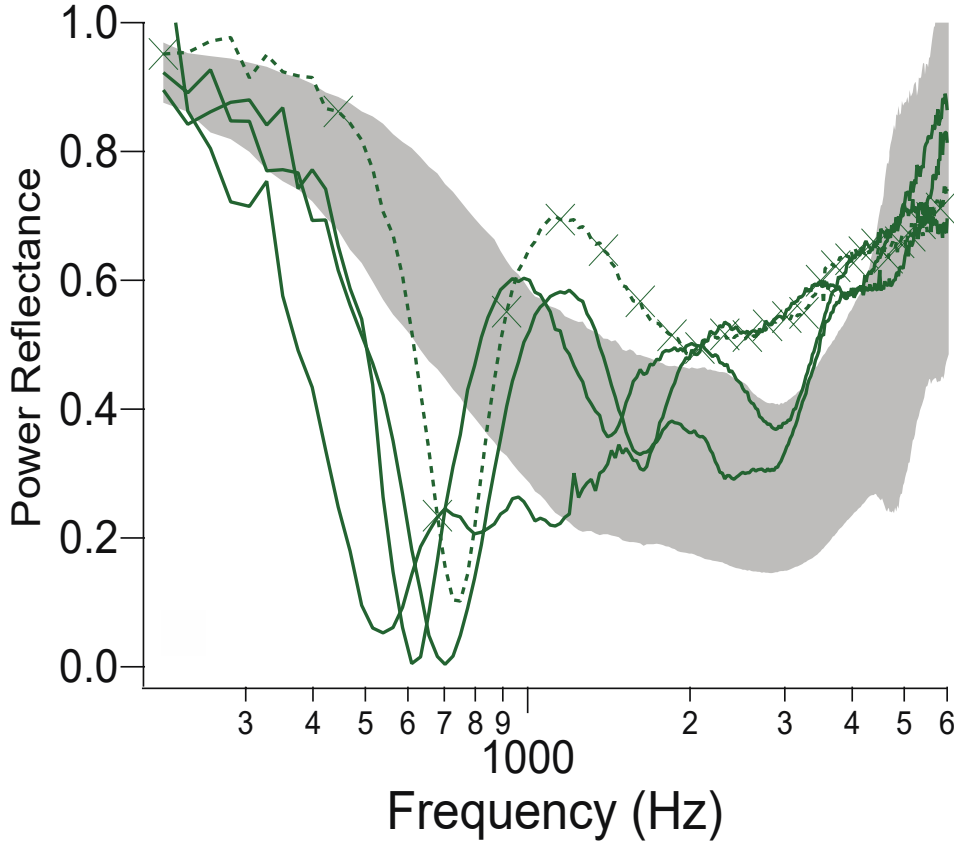


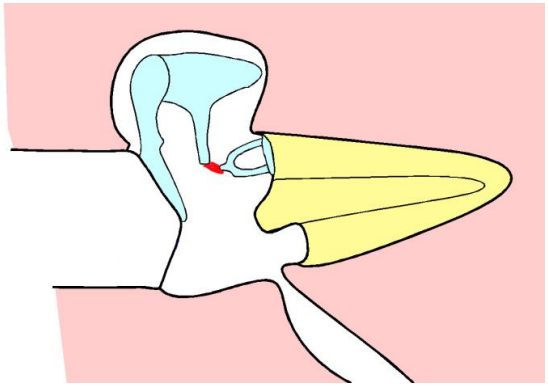
Nakajima et al 2012

Increased PR from 200-1000 Hz

BOYS TOWN National Research Hospital

Ossicular Discontinuity



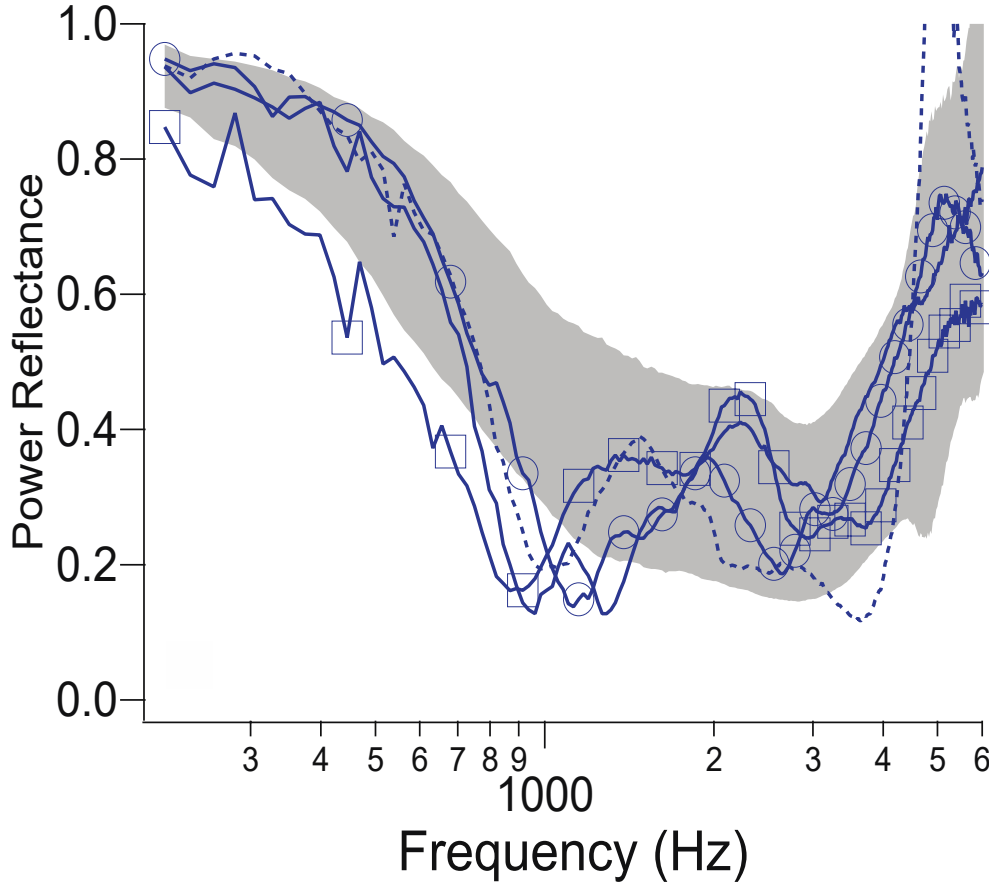


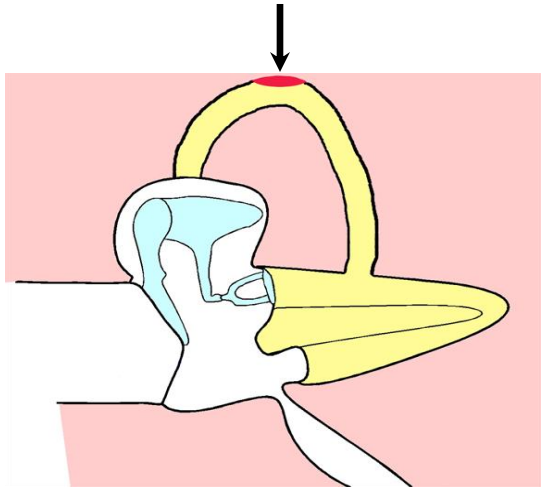
Deep notch in PR around 700 Hz

Nakajima et al 2012

BOYS TOWN National Research Hospital

Superior Semicircular Canal Dehiscence



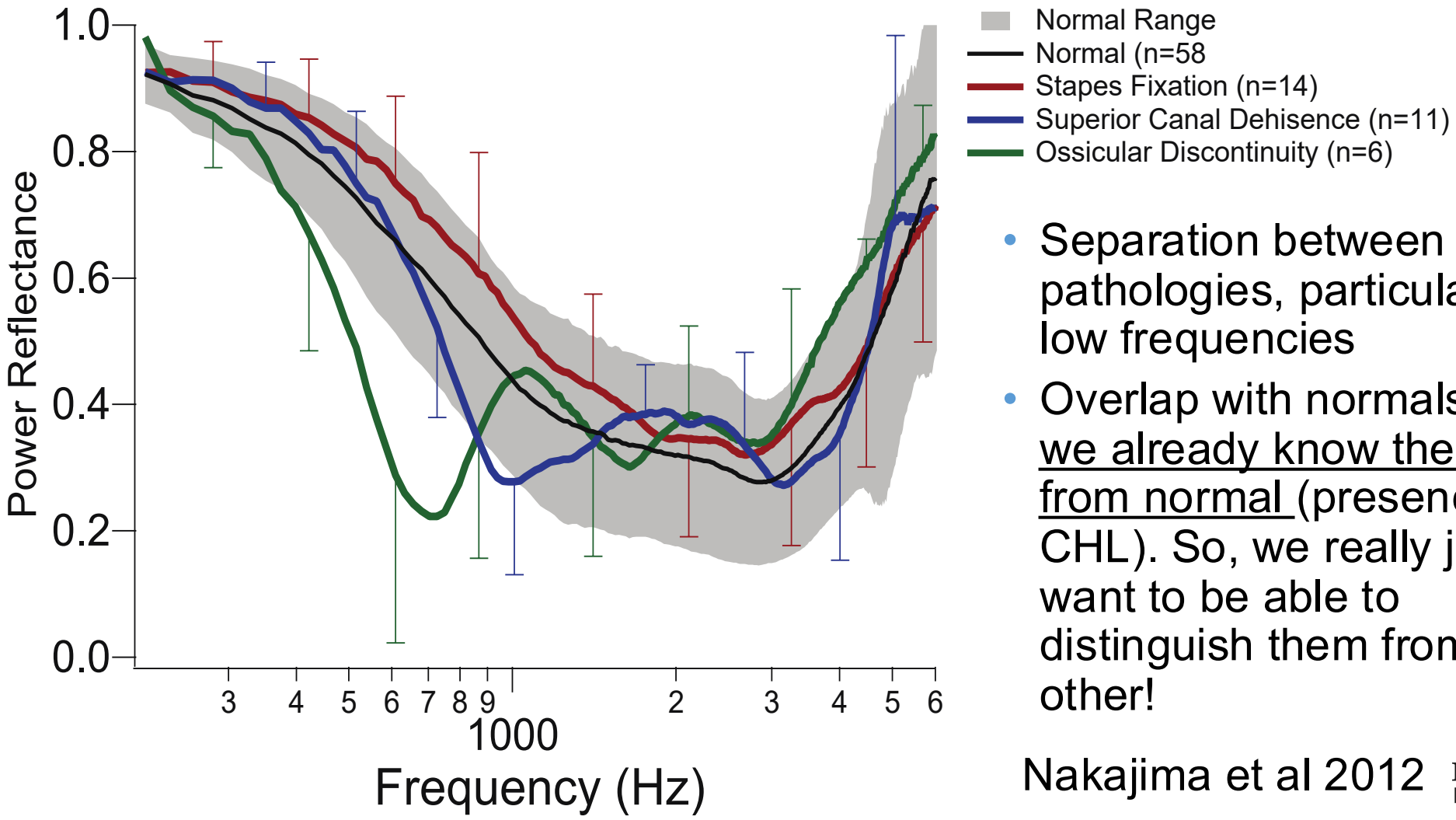


Notch in PR around 1000 Hz

Nakajima et al 2012

BOYS TOWN National Research Hospital

Comparison of Mean PR for CHL Pathologies



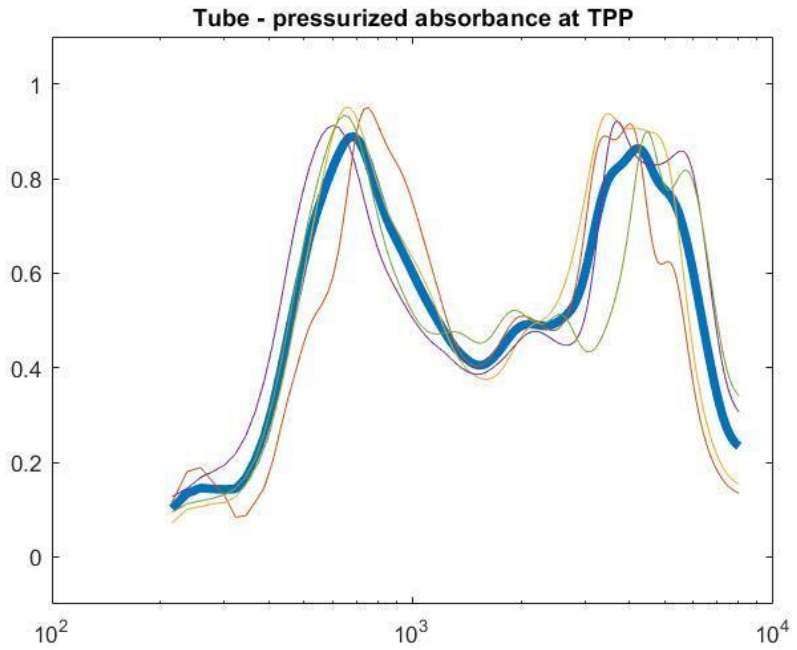
- Separation between three pathologies, particularly at low frequencies
- Overlap with normals, <u>but we already know they differ from normal</u> (presence of CHL). So, we really just want to be able to distinguish them from each other!

Nakajima et al 2012

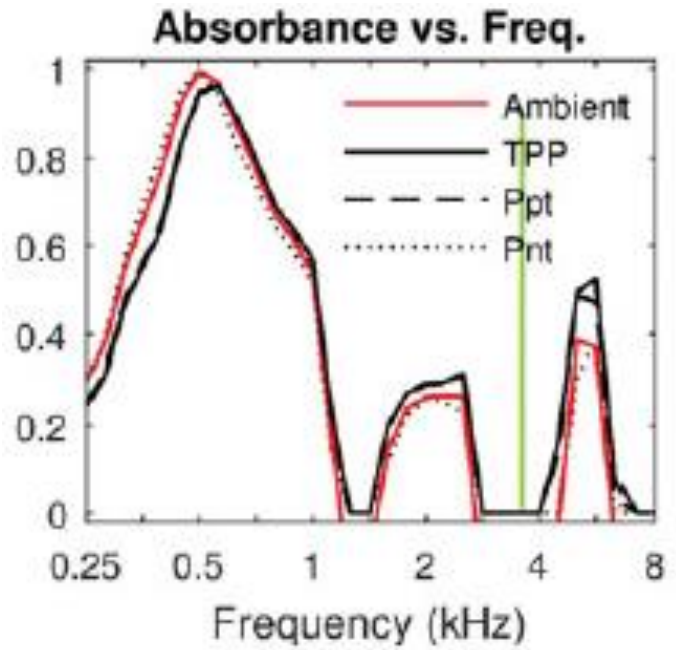
BOYS TOWN National Research Hospital

Patent Tubes

Po



Merchant et al, unpublished



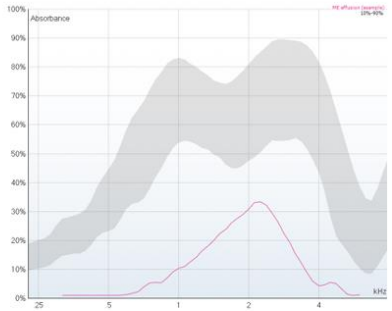
Hunter et al 2017

Patent tubes show multiple large dips / peaks (resonances)

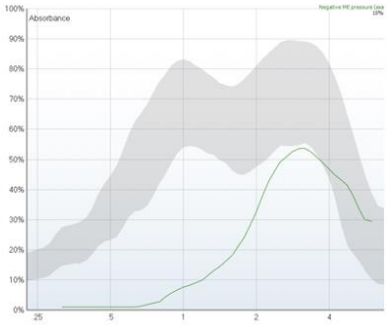
BOYS TOWN National Research Hospital

Summary

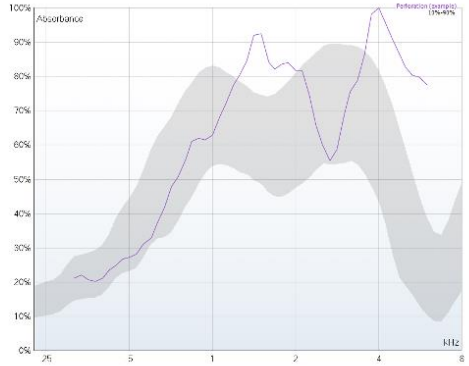
Middle Ear Effusion: Reduced absorbance at all frequencies.



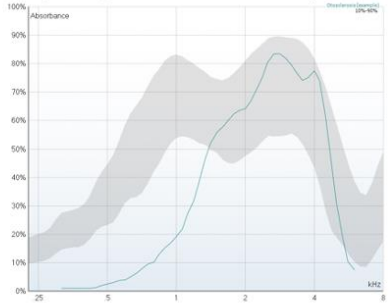
Negative ME Pressure: Reduced absorbance below 2000 Hz (can be well out of normal range or just borderline low).



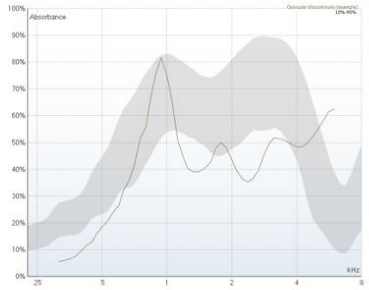
Patent Tube or Perforation: Multiple pronounced peaks.



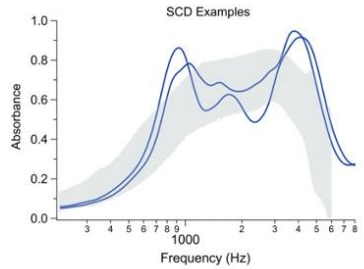
Otosclerosis: Reduced absorbance below 2000 Hz (can be well out of normal range or just borderline low).



Ossicular Discontinuity: Pronounced peak in absorbance around 1 kHz.



Superior Semicircular Canal Dehiscence: Multiple peaks, with one usually around 1 kHz.



These examples are built into the Interacoustics device

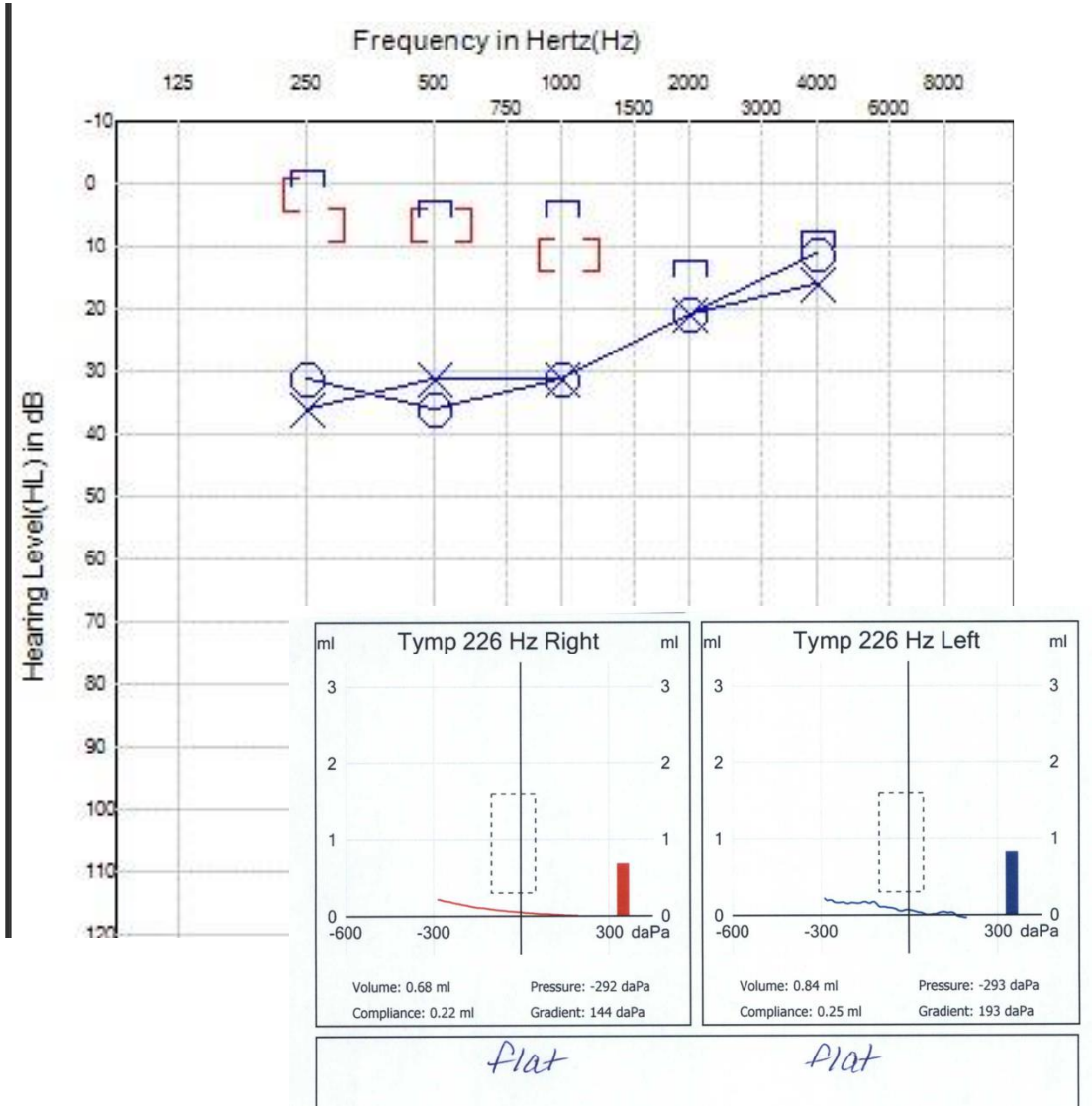
BOYS TOWN National Research Hospital

Putting it to practice.. Pathology puzzle!

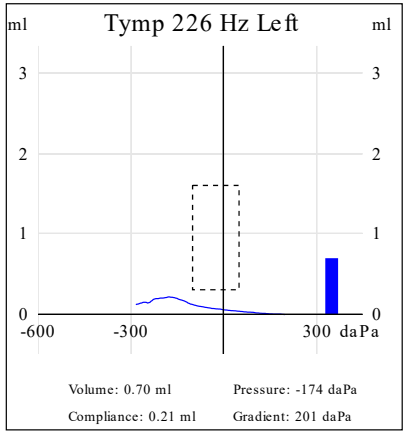
- 8-year-old male
- Seen in clinic for suspected otitis media
- Bilateral Flat Tymps
- Bilateral CHL
- ENT couldn't visualize fluid, but assumed it was present, and scheduled for BMT
- Enrolled in BTNRH OM Study

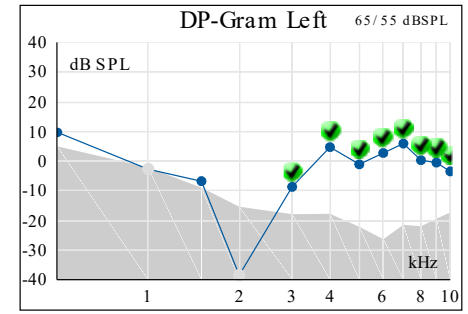
Assessment/Plan

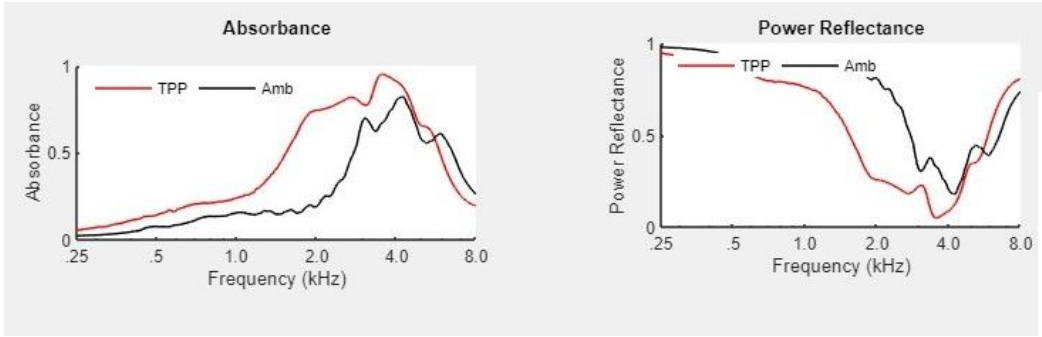
#	Detail Type	Description
1.	Assessment	Conductive hearing loss, bilateral (H90.0).
	Patient Plan	Audiometric studies today demonstrate bilateral low-frequency conductive hearing loss and flat tympanogram. On otologic exam I thought the middle ear was aerated. We repeated his tympanogram flat again. He has had hearing loss identified over the last 6 months. We discussed the common nature of middle ear fluid or dysfunction in this age group. BMT was recommended. We discussed the decision making in the anticipated benefit. I reviewed the risks including need for tympanostomy tube removal and tympanic membrane. We also discussed the importance of postoperative audiometric testing.

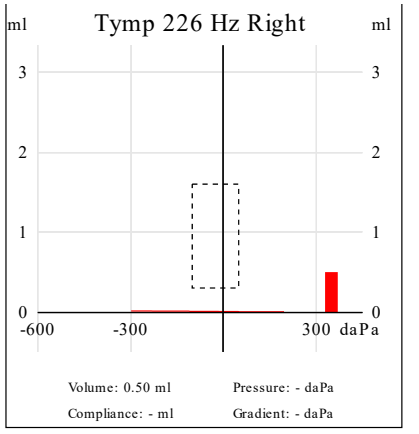


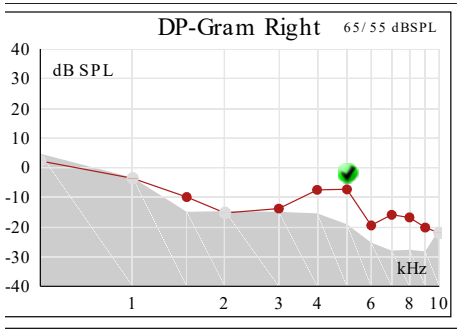
When things don’t add up…

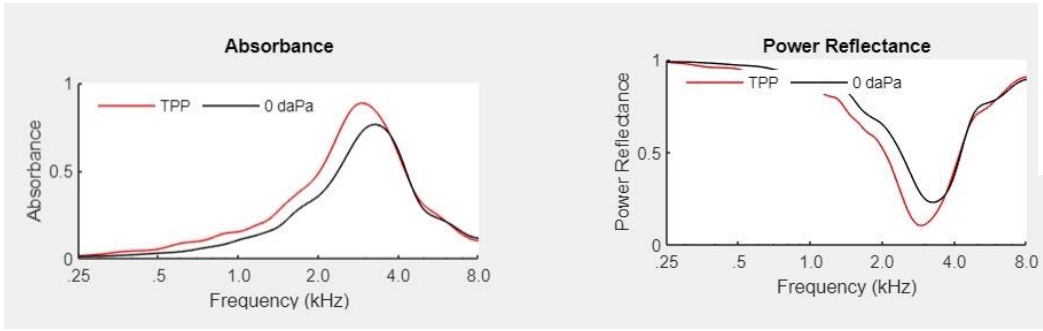


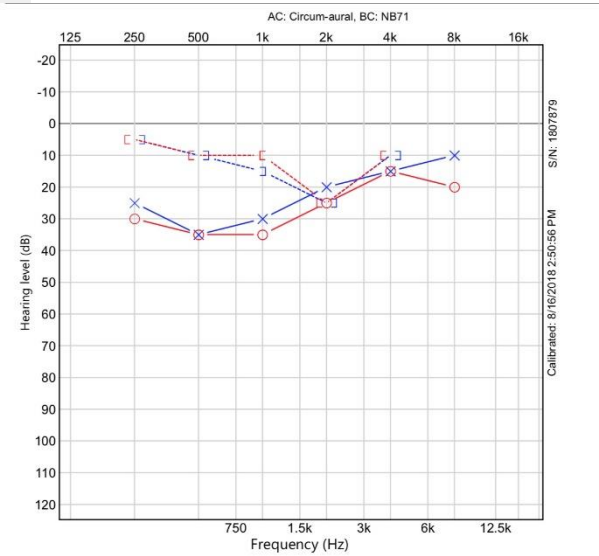






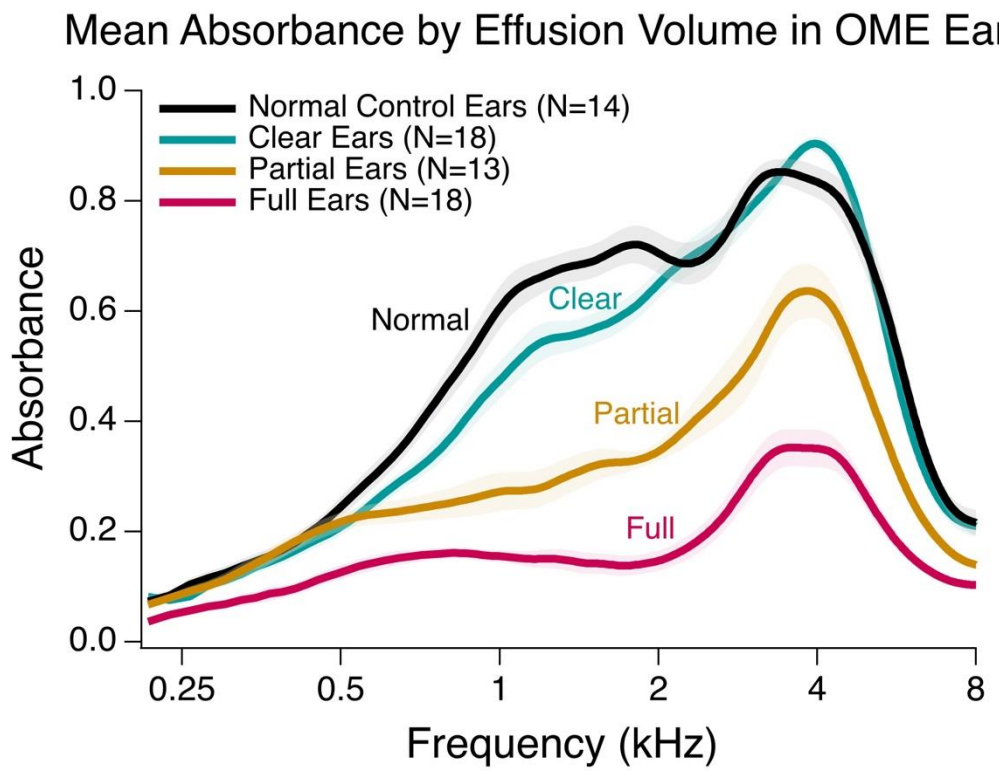




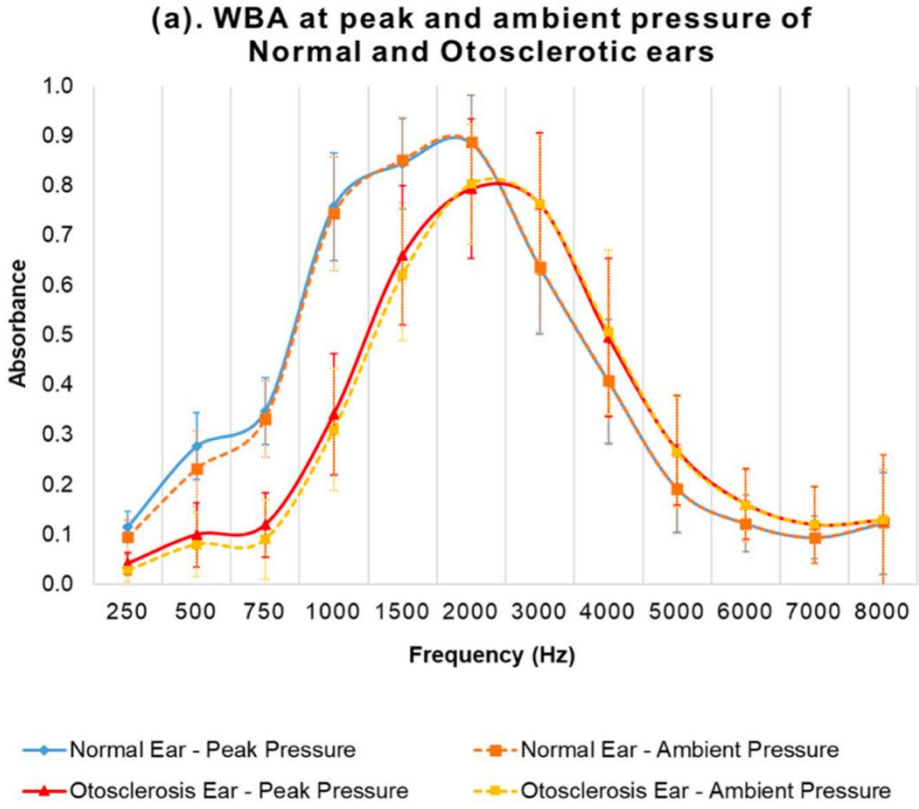


BOYS TOWN
National Research
Hospital

Fluid? Or Ossicular Fixation?



Merchant et al., 2021



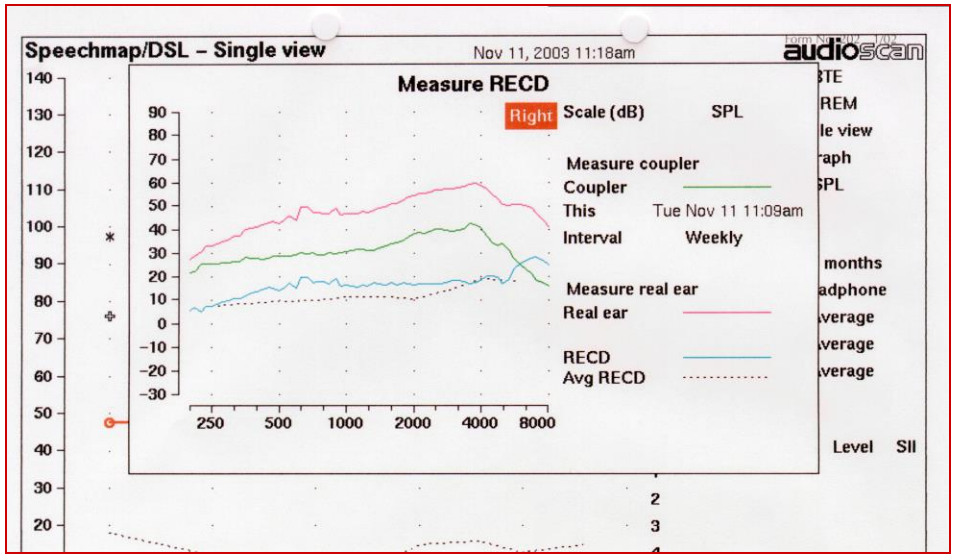
Karuppannan & Barman, 2020

BOYS TOWN National Research Hospital

RECD Prediction

Can we use WBT to predict RECD?

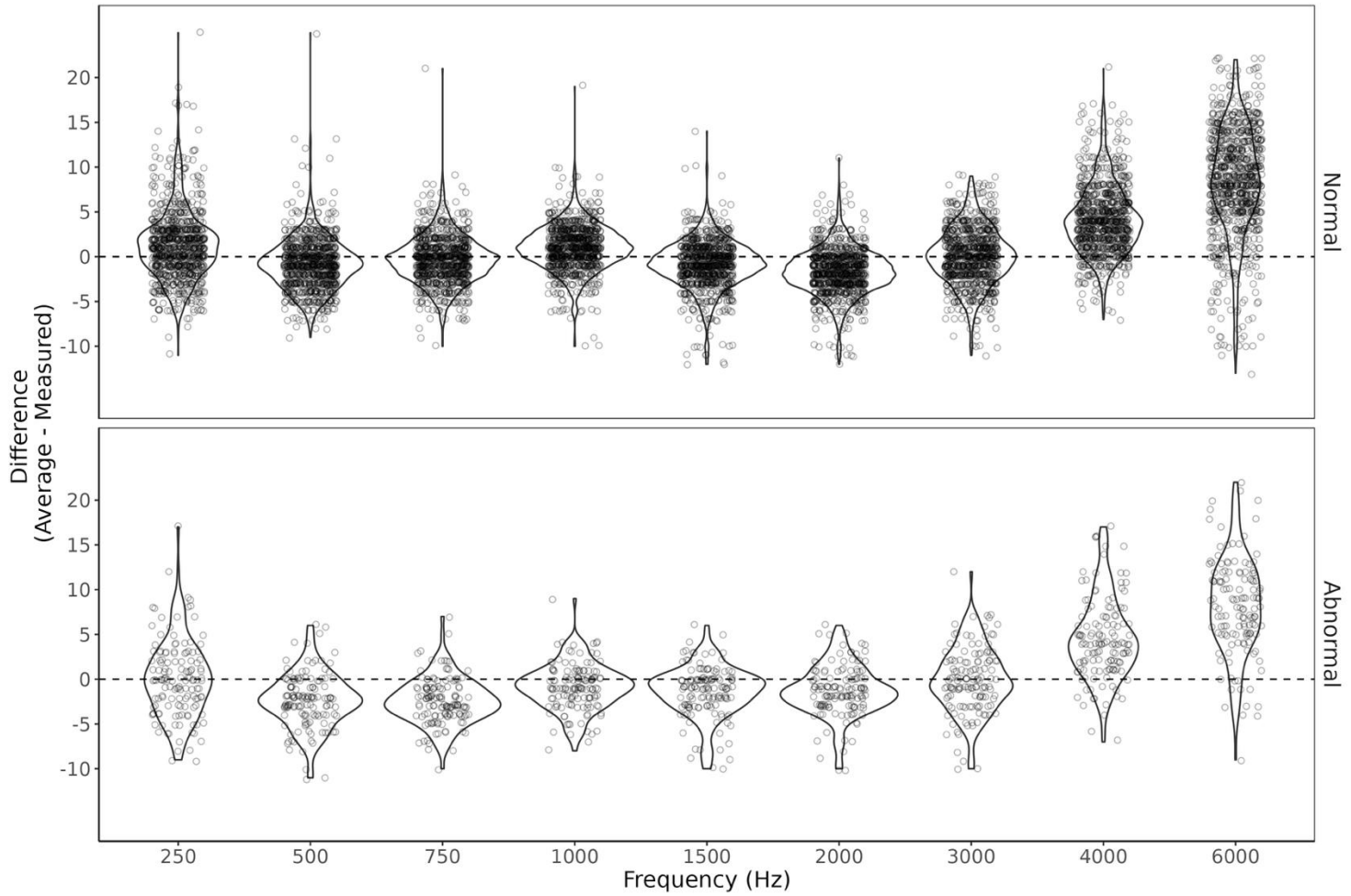
- RECD is often used for pediatric hearing aid fittings when real ear measures are not feasible
  - But in many cases, still can't get the RECD
  - In this case, people tend to use average RECDs for age, but this can result in large errors (up to 20 dB)
- Used a Bayesian approach to determine if we could predict RECD from WBT, as it is also a measure of the acoustics of the ear canal



McCreery et al. 2023/2024

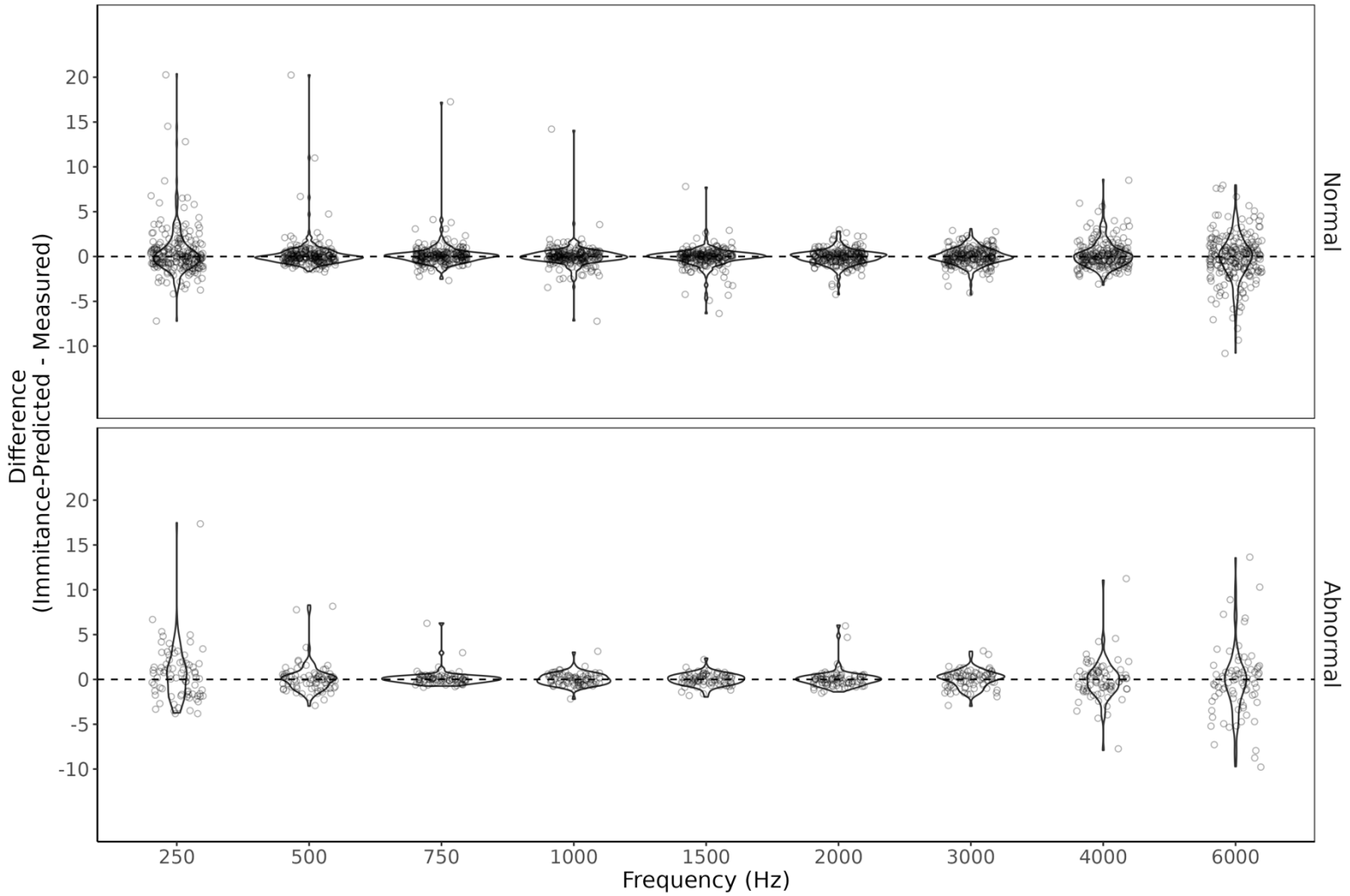
BOYS TOWN National Research Hospital

Average RECD vs. Measured



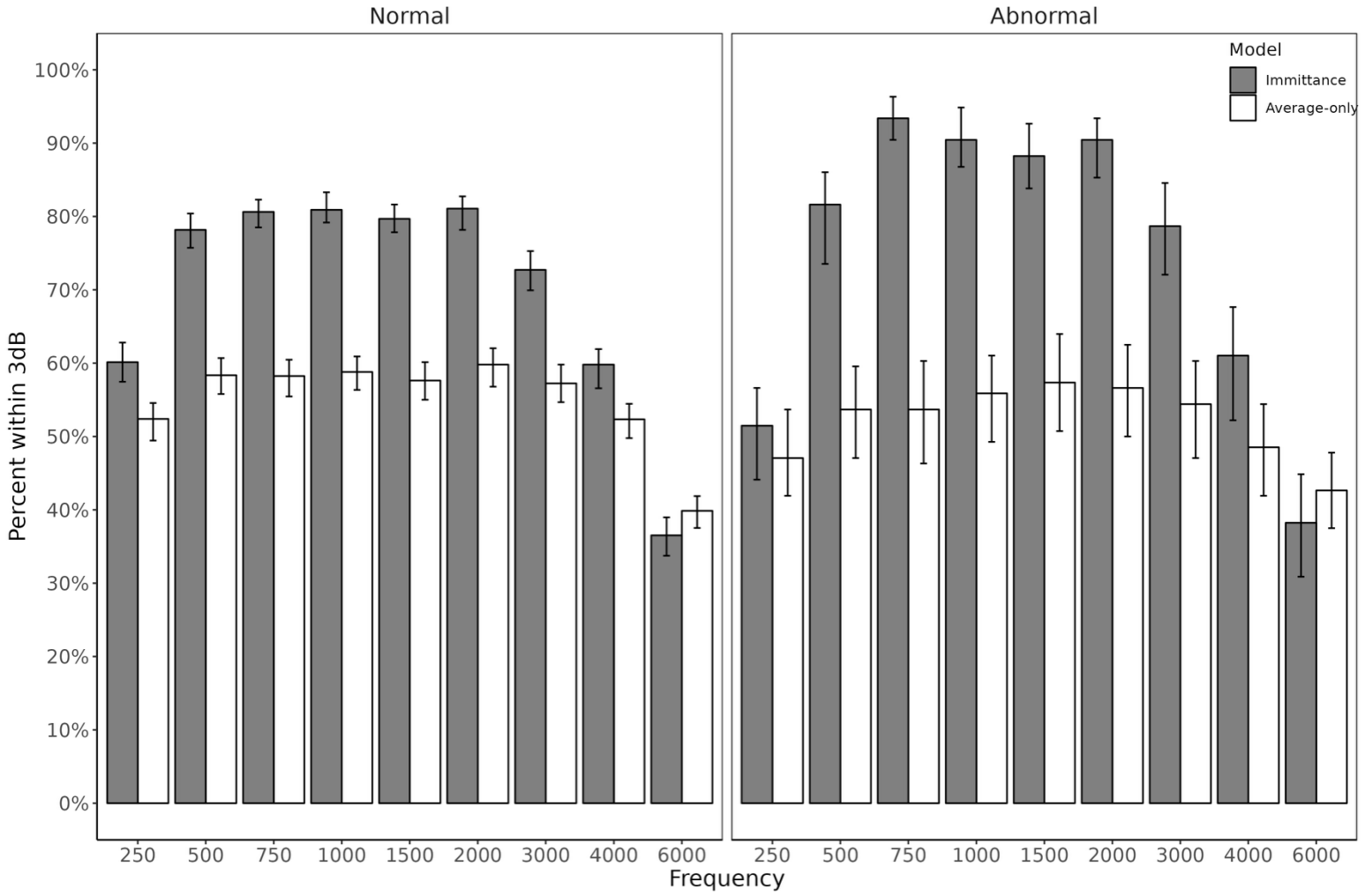
BOYS TOWN
National Research
Hospital

WBT Predicted RECD vs. Measured



BOYS TOWN
National Research
Hospital

Percent of RECDs within 3 dB



BOYS TOWN National Research Hospital

Conclusion

- WAI is relatively inexpensive, quick and generally easy to measure
- WAI, absorbance, PR, or whatever you decide to call it has a great deal of clinical utility as a non-invasive diagnostic measure for a wide range of pathologies
- The WAI device can also be used for other diagnostic purposes in clinics that are already routinely performed, such as OAEs, Tympanometry, ABRIS, and MEMR

- Why aren't we using it? Requires new equipment and training. Not as straightforward to interpret as tympanograms. Collaborating providers don't know what it is (ENT, Peds, Internal Med). Field is slow to change. Some clinics are beginning to use it, and the more research and training that is put out there, the more we can improve it, and make it more accessible on a widespread basis!

Thank you to…

TAPP Lab Members
Sarah Al-Salim, AuD
Rick Tempero, MD, PhD
Jane Khin, AuD
Leah Gibbs, AuD
Hannah Johnson
Delaney Skretta
Lauren Crowther
Hannah Green
Nafeesah Husain
Anna Schulte










Collaborators
Stephen Neely, ScD
Emily Buss, PhD
Ryan McCreery, PhD
Jeff Crukley, PhD

Recruitment and data collection support from:
BTNRH Tech Core (Denis Fitzpatrick, PhD)
BTNRH Audiology
BTNRH ENT (especially Kelli Rudman, MD)
BTNRH Pediatrics
BTNRH Surgical Staff

This work is generously supported by funding from NIH NIDCD and NIGMS

P20GM109023 (NIGMS)
R56DC021320 (NIDCD)
L30DC017300 (NIDCD)
R01DC021320 (NIDCD)

BOYS TOWN National Research Hospital

Thank you for your attention!

Gabrielle R. Merchant
Boys Town National Research Hospital
555 N 30th Street
Omaha, NE 68131
Gabrielle.Merchant@boystown.org
(531) 355-6368

BOYS TOWN National Research Hospital