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The Case for Incorporation of Wideband Immittance Testing in Newborn and Infant Hearing Screening: Practical and Theoretical Considerations, in partnership with Seminars in Hearing

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Disclosures

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Learning Outcomes

<u>After this course, participants will be able to</u>:

1. Describe wideband absorbance (WBA) in normal infant ears and assess abnormal WBA in ears with obstructed sound conduction pathways.
2. Explain how to create appropriate recommendations for re-screening or diagnostic testing using outcomes of both wideband immittance and hearing screening tests.
3. Discuss the importance of acoustic seal with WBA testing, and methods to ensure appropriate probe tip fitting.

Universal Newborn Hearing Screening (UNHS) & EHDI Programs

- **<u>Timeliness</u>** of intervention is paramount in preventing lasting impacts of congenital hearing loss..
  - E.g., on language, speech, cognitive development.
- Guidelines for EHDI programs **(JCIH, 2019):**
  1. **Identify** *<u>permanent congenital hearing loss</u>* by **1 month** of age.
  2. **Diagnose** hearing loss by **3 months** of age.
  3. **Intervene** by **6 months** of age.

Problem: Obstructions of sound conduction pathway at birth → high false positive rate!

- Naturally occurring..
  - Ear canal vernix.
  - Tympanic cavity residual developmental tissue.
  - Amniotic fluid aspirations.
- Transient in Nature..
  - Resolves 2-3 days after birth.
- Impact on OAE and AABR screening tests:
  - 76-92% of referrals to outpatient screening **(Thompson et al., 2001)**.
  - Further complicated by loss-to-follow-up.
  - Cost-efficiency burden.
- Contributes to delayed intervention.
  - Only 67.3% receive timely interventions! **CDC (2017)**

Summary: Impact of transient conductive obstructions on UNHS outcomes..

Fact: Most babies fail hearing screening due to transient conductive hearing loss..

Problem: But there is no way of determining this as cause of fail outcome at birth..

Therefore, ***all babies are indiscriminately rescreened two weeks later***: ***Extremely inefficient!***

Benefit of immittance testing at birth

Need: Incorporate a middle ear test at the time of birth!

Improvement in referral paradigms

Referral scenarios to consider:

- What if a baby refers on OAE or AABR but sound conduction is normal?
- What if baby refers on OAE or AABR, but sound conduction is abnormal? Slightly abnormal?

Need for alternative immittance tests in Newborns!?

Problems & Limitations of Tymponometry:

1. *Violated assumptions:*
   - Pressurization deforms the ear canal walls (***collapsed at negative pressure & distended at positive pressure***).
   - Ear canal wall vibrations at low frequencies!
   - At 1000 Hz, 1 mmho ≠ 1 ml or 1cc.

2. *Limited clinical utility.*
   - Variable norms, and inconsistent approaches to assessment for 1000 Hz-Tympanograms.

3. *Probed at discreet frequencies:*
   - Limited assessment of the conductive pathway
   - We hear at all frequencies!

Wideband Acoustic Immittance (WAI)

Advantages of WAI Tests:

1. Does not require pressurization of the ear canal..
   - Thanks to advanced calibration techniques!!
2. Ability to assess the conductive pathway function over a wide range of frequencies..
   - Representative of middle ear function.
   - More complete assessment of acoustic mechanics **(i.e., stiffness, mass, resonance)**
3. Multiple immittance measures can be derived:
   - Including: ***Im***pedance/ad***mittance*****,** power absorbance, power reflectance, impedance phase.
   - *Wideband [power] absorbance* ***(WBA)*** is increasingly adopted in clinical research, and increasingly adopted for clinical application!

Middle Ear Acoustic Mechanics

Natural Impedance & Resonance of the Middle Ear

Why objects vibrate at the frequency that they do?

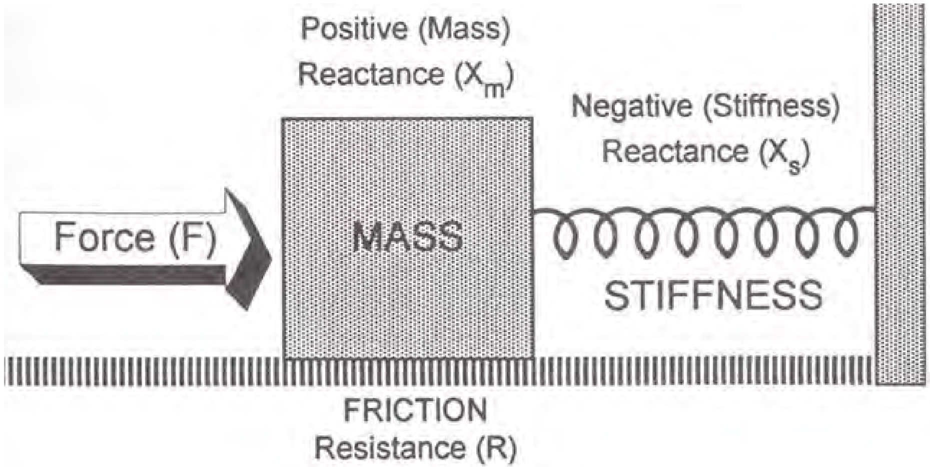
- **Impedance:** Physical properties that hinder sound vibrations.
- **Natural [resonant] frequency** of objects
  → **The frequency at which impedance is the smallest.**
- The middle ear conducts sound best at its natural [resonant] frequency

- $Z = iR + j(X_M - X_S)$
  - *R*= Resistance (e.g., friction)
    X= Reactance
- $Z = \sqrt{(R^2 + (2\pi Mf - k/2\pi f)^2)}$
  - ***f*** = frequency of sound going through the system
  - *M* = mass **(frequency dependent)**
  - *k* = stiffness constant **(frequency dependent)**

Middle Ear Acoustic Mechanics

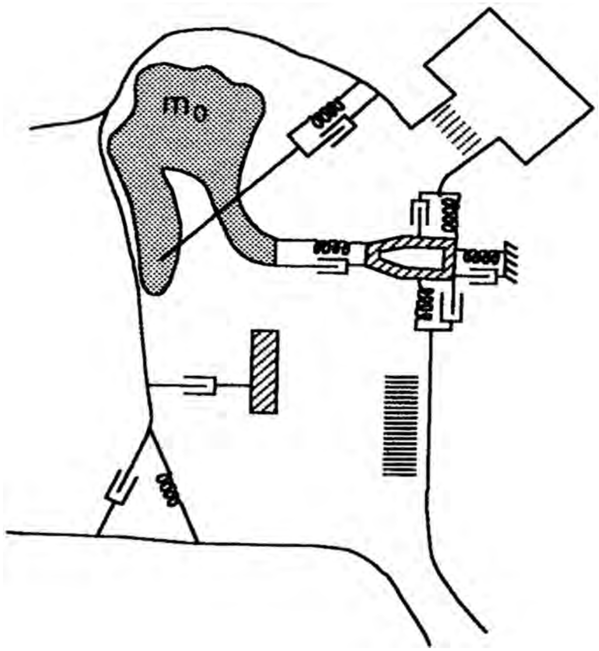
Natural Impedance & Resonance of the Middle Ear

- The middle ear system will vibrate most optimally at its natural "tuning"/ resonant frequency;
  - ***This is the frequency at which Z is lowest***
- The physical properties of stiffness, mass, & resistance determine the impedance **(Z)** of the middle ear.

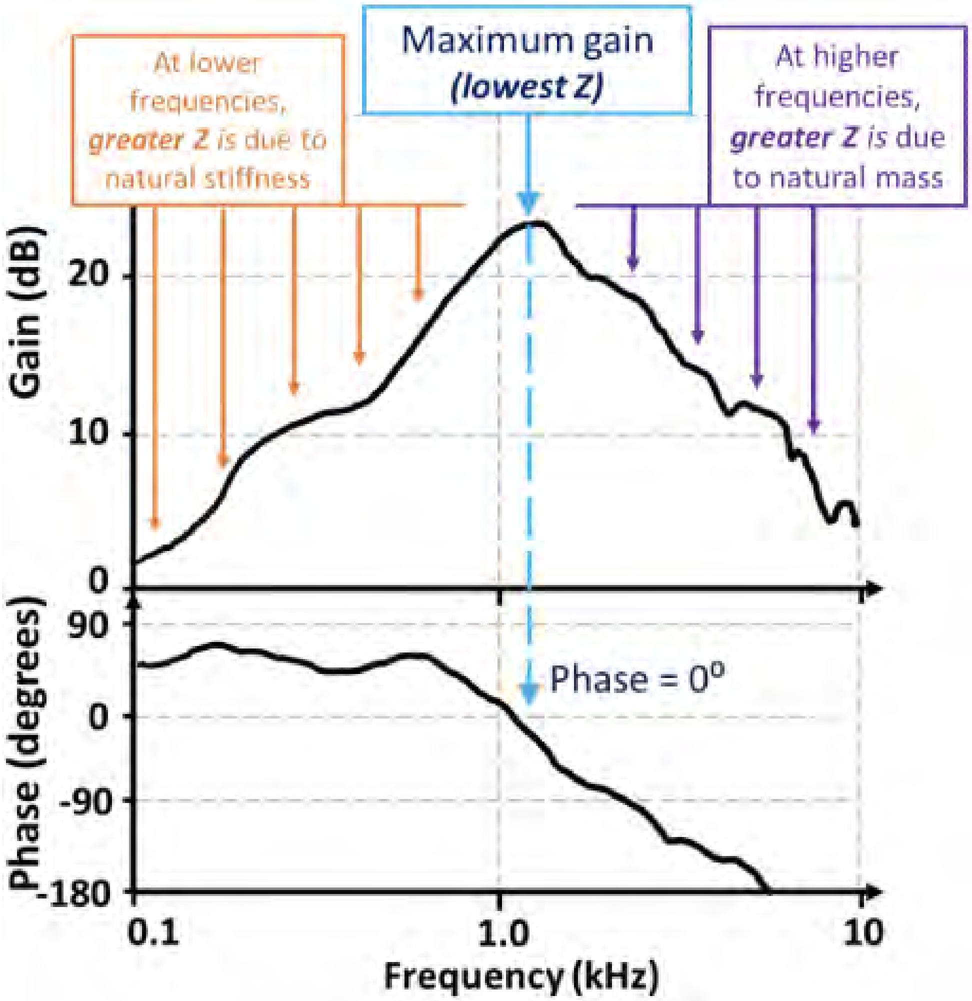


Middle Ear Acoustic Mechanics

Marquet et al. (1973)



Adapted from Aibara et al. (2001)



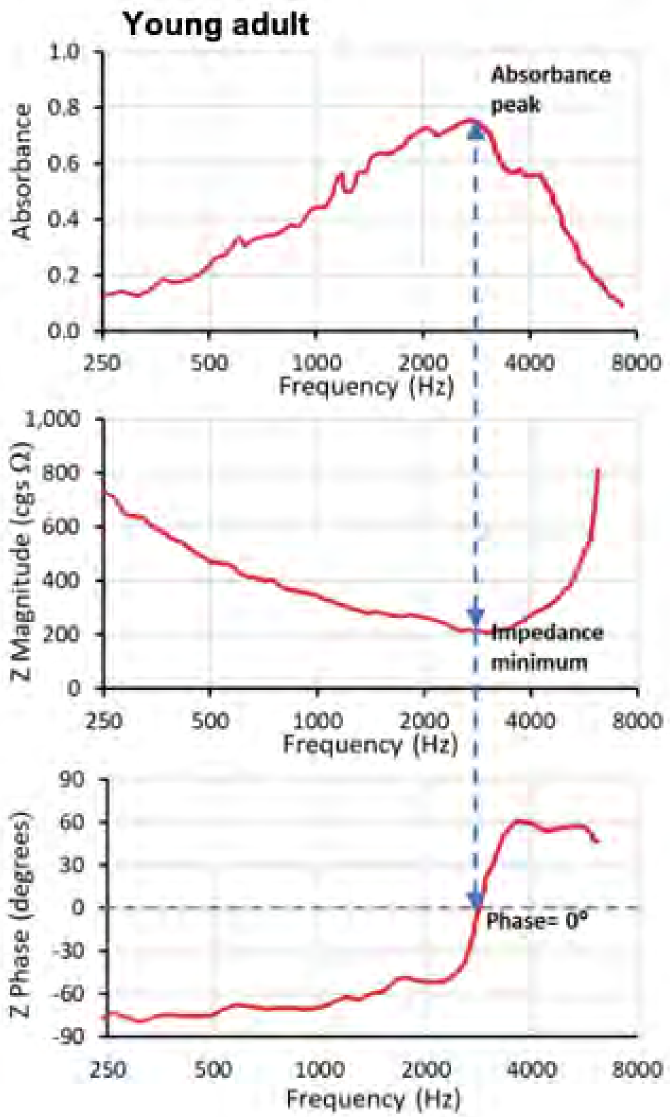
$$Z = iR + j(X_M - X_S)$$

Stiffness: e.g., of TM, ligaments, joint articulations, air volume.
Density: e.g., of bones, TM
Resistance: e.g., frication at joints

Wideband Acoustic Immittance (WAI)

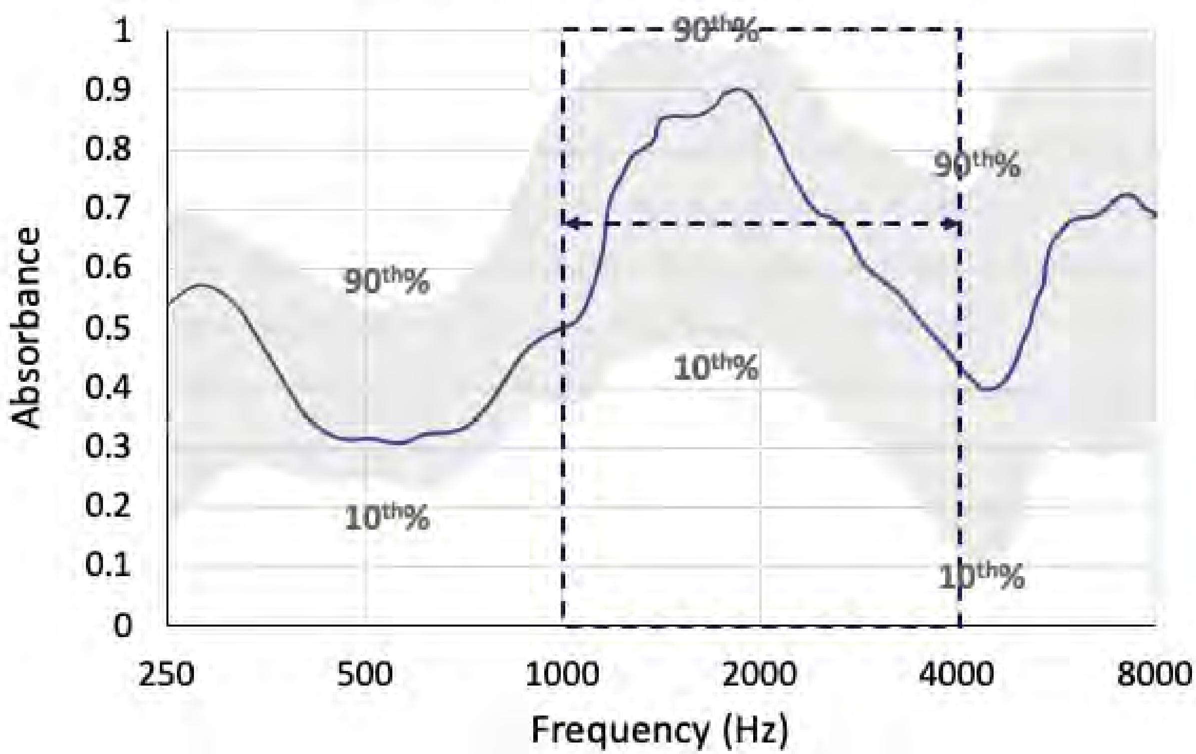
WAI are clinical measures that approximate middle ear transfer function…

- **Power Absorbance** $= \dfrac{\color{red}{Absorbed}\ power}{\color{purple}{Incident}\ power}$
- **Other WAI measures include:** *impedance magnitude, phase, or power reflectance.*
- **Commercially available systems:**
  - *Interacoustics's Titan*
  - *GSI's Tympstar Pro*
  - *Mimosa Acoustics's HearID*

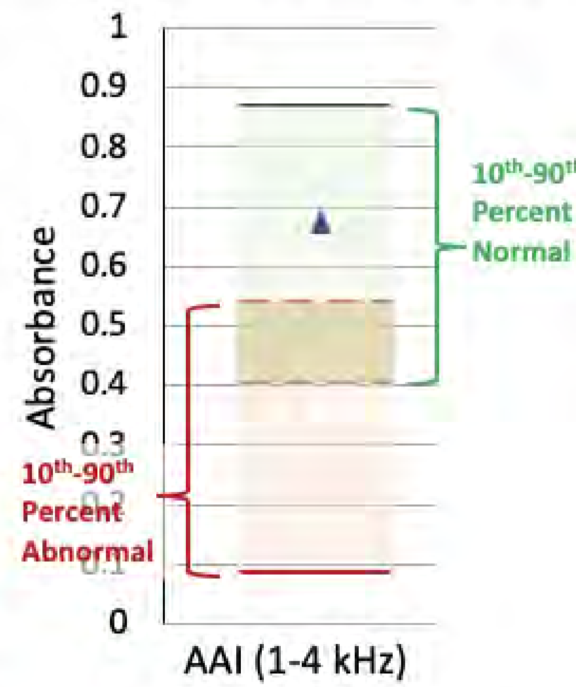


Characteristics of normal WBA in newborns

WBA Normative range



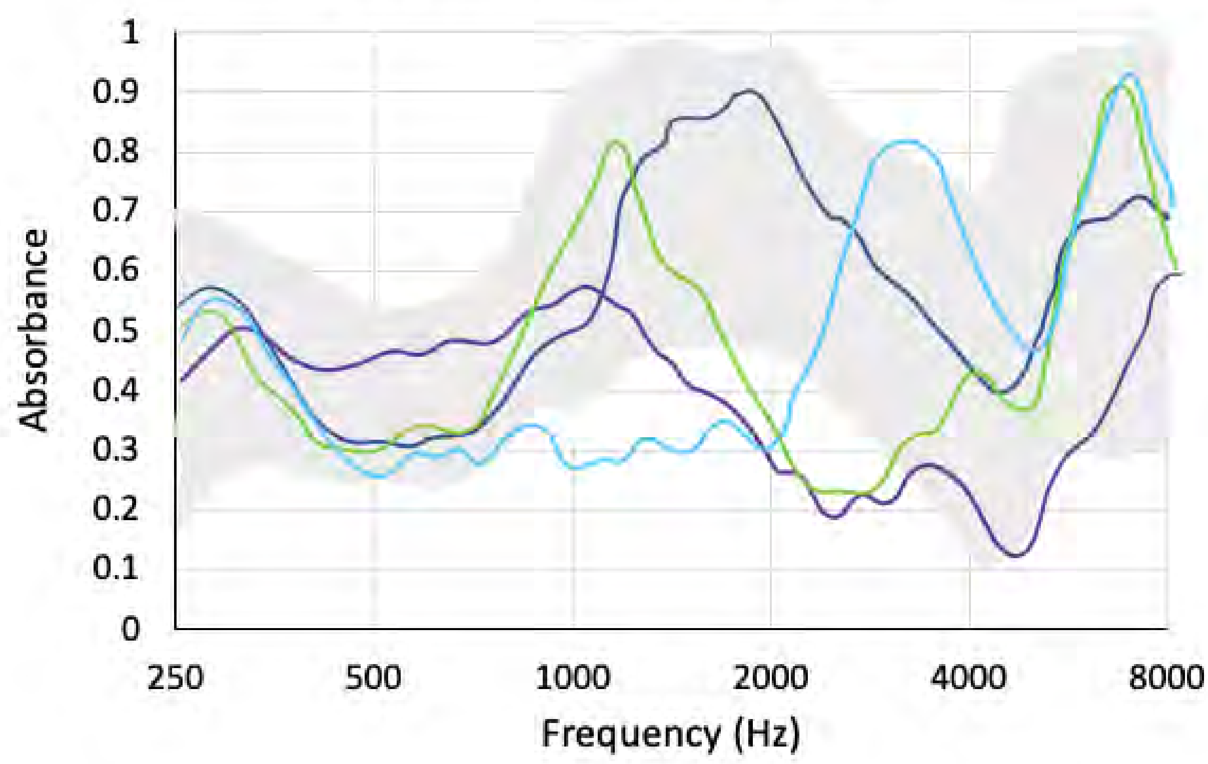
Absorbance Area Index



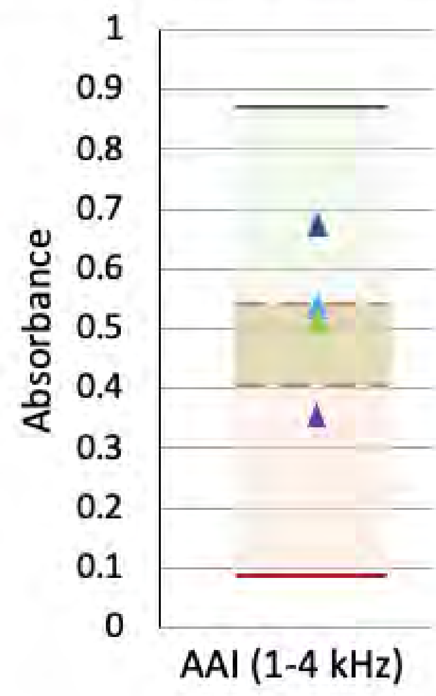
Normative values adapted from Hunter et al. (2010)

Assessment of abnormal WBA

WBA Normative range

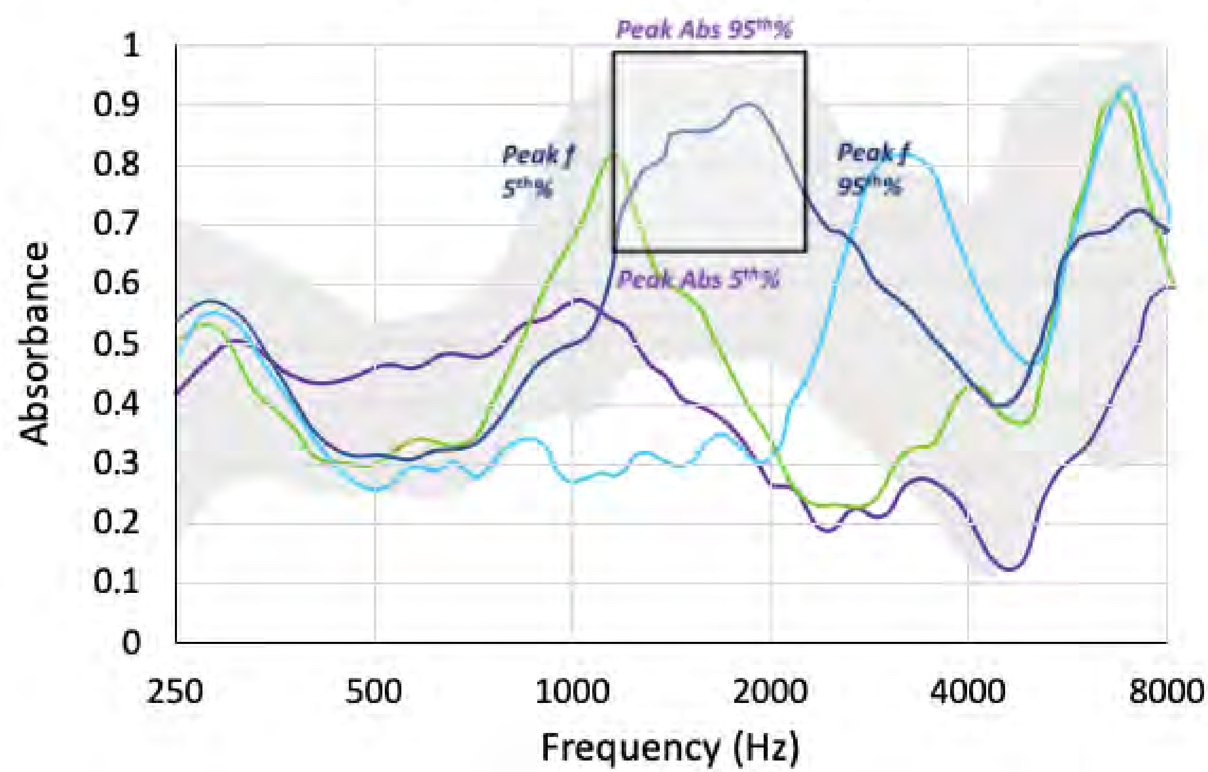


Absorbance Area Index



Alternative assessment paradigm..

Absorbance peak analysis



AlMakadma & Sanford (2023)- In revision

Absorbance Peak Template (APT)

- Analyze peak absorbance & peak frequency
- Similar test accuracy as AAI.
- Simpler interpretive paradigm:
  - *Is peak absorbance low?*
  - *Is peak frequency shifted higher-/lower-than-normal?*

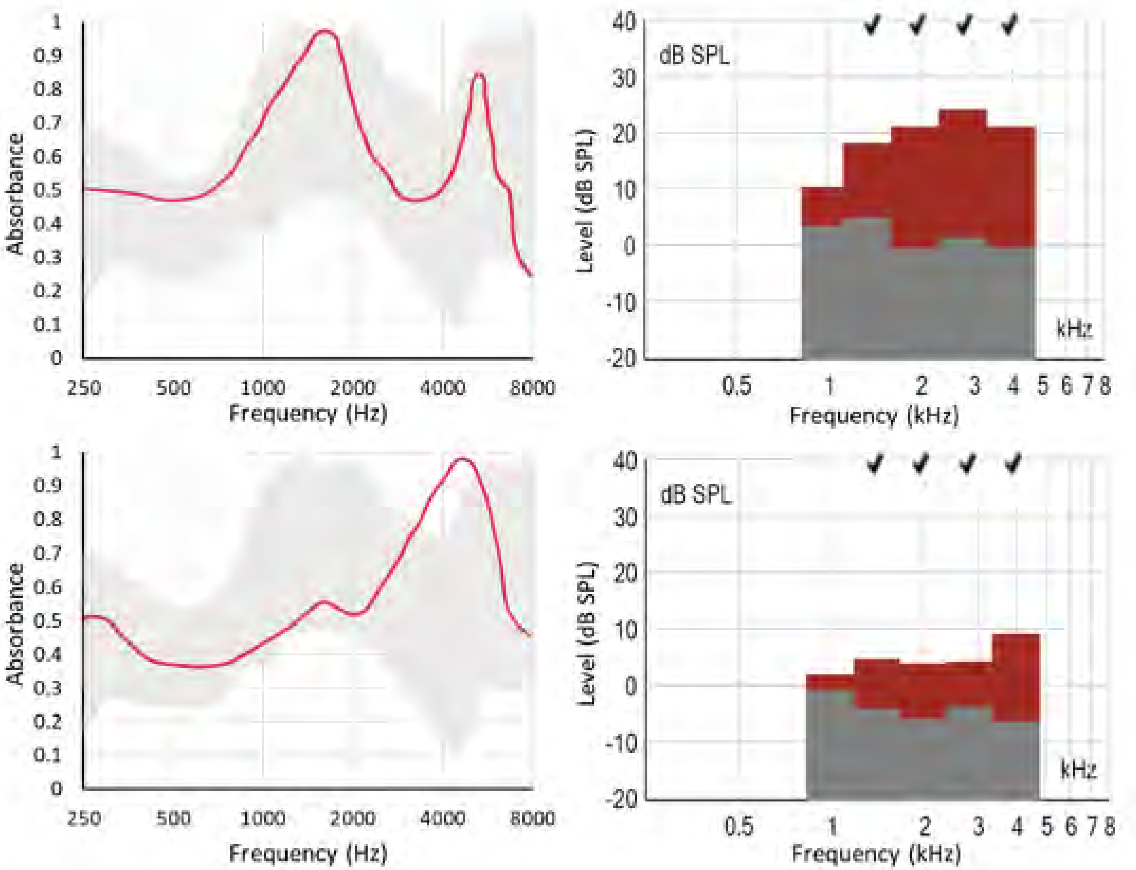
Back to Newborn Hearing Screening…

How to use WBA and NHS outcomes together?..

- Different referral recommendations based on WBA findings..
  - When WBA is normal → prioritized for ***diagnostic evaluation***.
  - When WBA is abnormal → schedule for ***outpatient follow-up***.

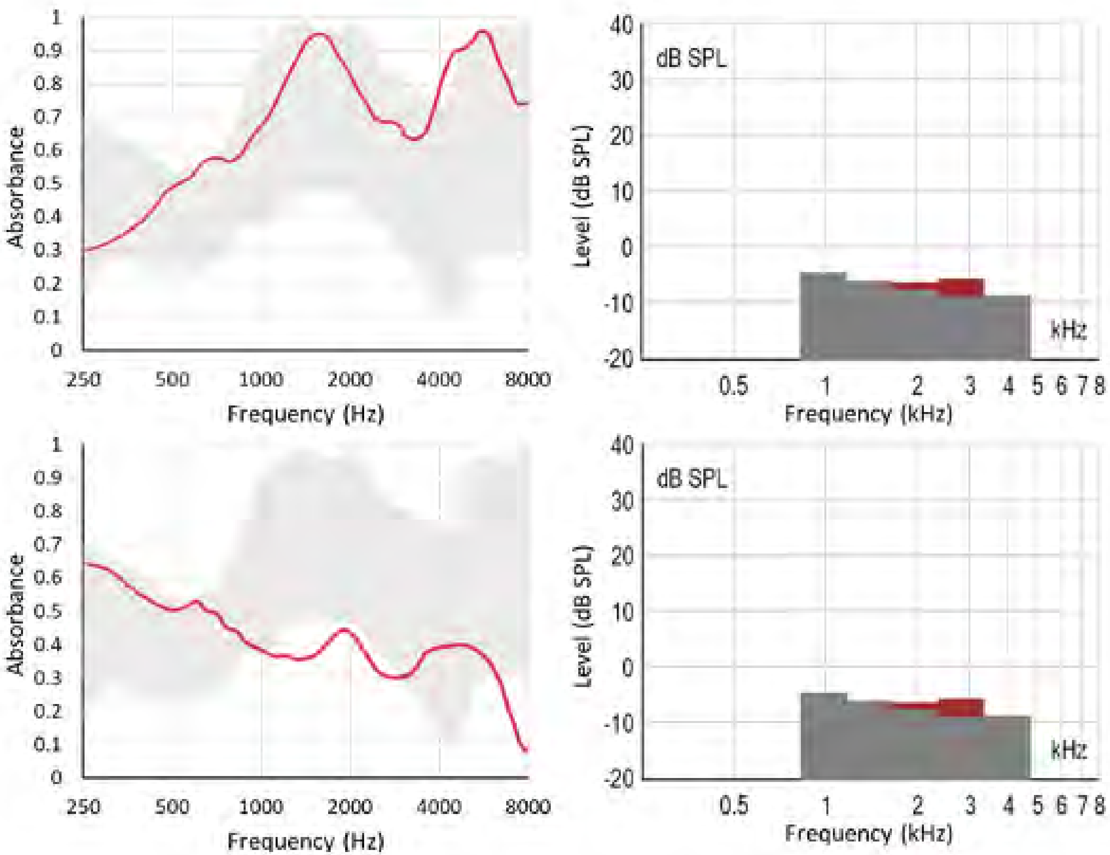
Screening test outcomes	WAI test outcomes	Recommendations
AABR/ OAE (Fail)	Normal WBA	Prioritize for diagnostics
AABR/ OAE (Fail)	Abnormal WBA	Rescreen after a few days
AABR/ OAE (Pass)	Normal WBA	Discharge / targeted surveillance
AABR/ OAE (Pass)	Abnormal WBA	Discharge / targeted surveillance

(1) Examples of WBA findings: **TEOAE-Pass**



- Normal WBA predicts *OAE-pass* outcomes in 94% of cases.
- Slight abnormalities in WBA reduce OAE levels, resulting in marginal increase in fail rate..
  - *Decrease in OAE-pass rate to 91%.*

(2) Examples of WBA findings: **TEOAE-Fail**



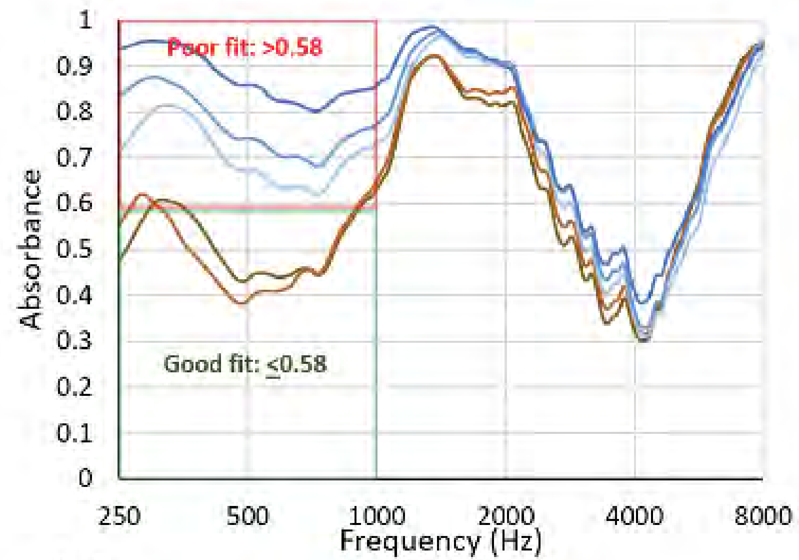
- Failed TEOAE with normal WBA indicates permanent SNHL..
  - High value cases.
  - Skip follow-up screening!!
- Otherwise, abnormal WBA results in TEOAE-Fail.
  - Due to temporary CHL.

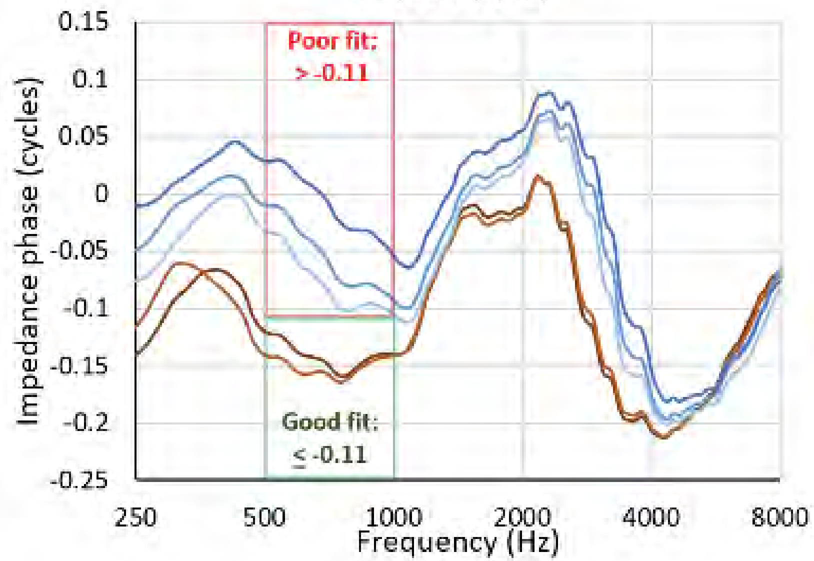
Practical Considerations…

- WBA measures are reliable!
  - Inter-class correlation >.68 **(Hunter et al., 2008).**
  - Mean $|\Delta$Test-retest$| \approx 0.05$; $90^{th\%} \approx 0.1$ **(AlMakadma & Prieve, 2021).**
- Testing is efficient!
  - Takes only 16 seconds to complete.
  - Less prone to environmental noise than OAEs.
- Procedural considerations:
  - *Careful probe tip insertion..*
  - *Acoustic air leaks..*
  - *Occlusion of probe tips..*
  - *Collapsed newborn ear canal walls..*

(1) Acoustic air leaks..

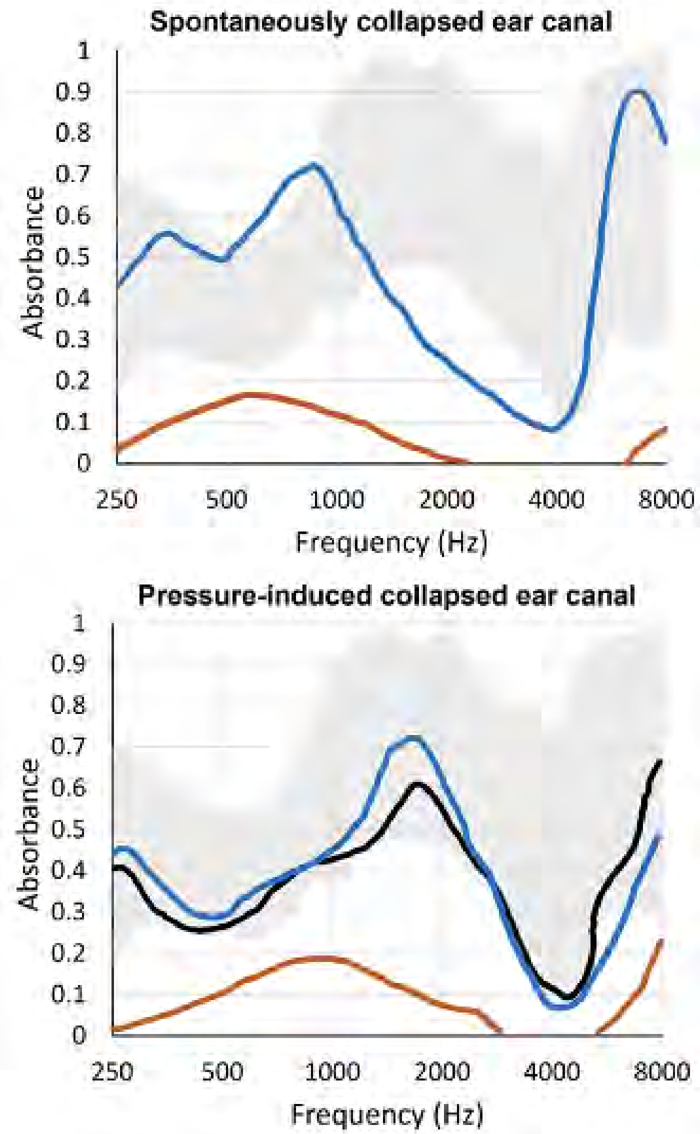
- Poor probe tip fitting leads to loss of acoustic air seal.
- Common in newborns:
  - Babies move a lot..
  - Small ear canal openings (diameter < 4 mm).
- Leads to artificial inflation of low-*f* absorbance!
  - Energy is lost, not absorbed.
- Indicated by **probe-fit criteria** **(AlMakadma & Prieve, 2021)**:
  - *Low-f absorbance >0.58*
  - *Low-f Z phase >-0.11 cycles*





(2) Collapsed ear canals..

- Spontaneously collapsed ear canal walls at early hours of life.
    - Increased fail rate on AABR and OAE screening tests.
    - WBA measurements can be used to determine their presence!
- Experimental confirmation:
    - Pressure-induced collapse of ear canal walls.
    - Reversed with removal and refitting of probe.



continuED Hearing

Summary

- WBA measured at birth can improve referral paradigms and timeliness of intervention for congenital hearing loss.
- WAI testing is simple, reliable and time-efficient.
- Recent efforts improved WBA assessment and clinical interpretive paradigms.
- Improved quality control methods further refined WBA measures.

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**

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