The Important Role of Otoacoustic Emissions in Pre-School Hearing Screening

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The Important Role of Otoacoustic Emissions in Pre-School Hearing Screening

- **Learner Objectives:**
  1. **List three limitations of pure tone hearing screening in young (birth to 3 years) preschool children**
  2. **Cite three factors contributing to loss-to-follow up of infants who yield a ”refer” screening outcome**
  3. **Describe three specific advantages of OAEs in preschool hearing screening**

The Important Role of Otoacoustic Emissions in Pre-School Hearing Screening

- Introduction to Early Hearing Detection and Intervention (EHDI): 0-10 minutes
- Guidelines for preschool hearing screening and limitations of pure tone screening: 11-30 minutes
- Summary of research in support of OAEs in preschool hearing screening: 31-45 minutes
- Evidence-based strategy for applying OAEs in preschool hearing screening: 46-55 minutes
- Summary, questions & answers: 56-60 minutes

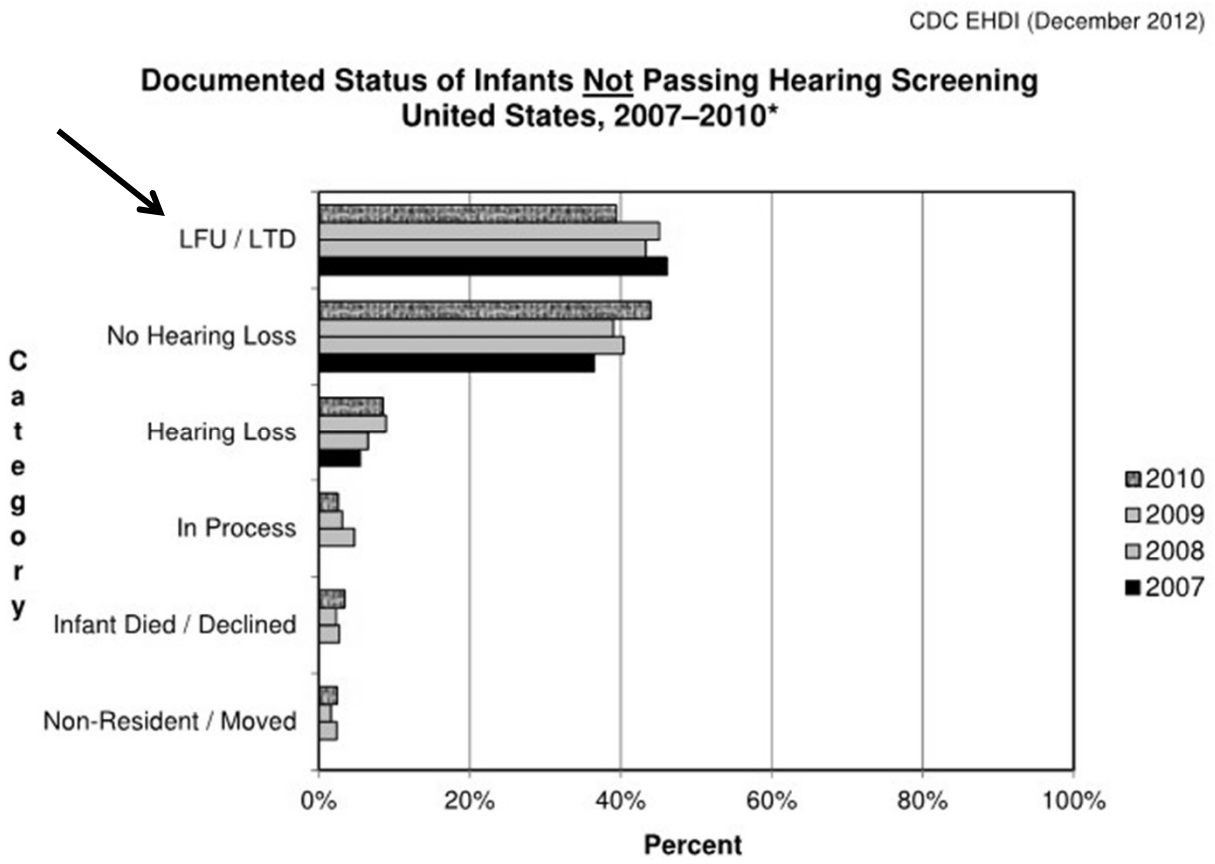
Early Hearing Loss Detection and Intervention:
The Ideal 1-3-6 Approach to EHDI

- < 1 month
  - An infant is identified with hearing loss through hearing screening
- < 3 months
  - Hearing loss is diagnosed following JCIH guidelines
- < 6 months
  - Appropriate intervention is implemented based on diagnostic findings.

Early Hearing Loss Detection and Intervention (EHDI): *The Problem of "Loss to Follow Up"*

- Most (90 - 98%) newborn infants undergo hearing screening
- > 40% of the children who fail hearing screened do not undergo timely diagnostic evaluation
- Intervention can't begin without diagnosis
- Multiple and diverse reasons for infants "lost to follow-up"
  - Newborn infants discharged from nursery before screening
  - Infants transferred to another hospital before screening
  - Infants screened in one state and living in another state
  - Failure to document screening or diagnostic findings
  - Family reasons, e.g.,
    - ✓ Transportation problems
    - ✓ Misunderstanding about need for follow-up
    - ✓ Infant has no primary care physician (medically homeless)

Early Hearing Loss Detection and Intervention (EHDI):
The Problem of Infants "Lost to Follow Up (LFU)"



Early Hearing Loss Detection and Intervention (EHDI): *Solutions for the Problem of "Loss to Follow Up"*

- Well-organized systems for data management and tracking
- Education of
  - Hospital personnel
  - Primary care physicians and pediatricians
- Combination OAE/AABR hearing screening approach for lower failure rate and earliy diagnosis of hearing loss
- Diagnostic assessment immediately following screening failures in hospitals with audiology clinical services
- More qualified audiologists widely distribution throughout each state to provide diagnostic evaluations
- Tele-audiology strategies for diagnostic evaluations
- Pre-school hearing screenings

Early Hearing Loss Detection and Intervention (EHDI):
Pre-School Hearing Screening is a Logical Extension of EHDI

- **Sites or venues for pre-school hearing screening**
  - **Primary care physician's office**
    - ✓ **Well baby visits**
    - ✓ **Immunizations**
    - ✓ **Concerns about ear infections or hearing**
    - ✓ **Physician visits for non ear-related reasons**
  - **Head Start Programs**
  - **Pre-school educational programs**
  - **Day care facilities**

Early Hearing Loss Detection and Intervention (EHDI): *Rationale for Pre-School Hearing Screening*

- Permits identification of hearing loss in children who were not screened as newborns
- Up to 50% of children undergoing newborn hearing screening are "lost to follow-up (LFU)"
- Identifies children with delayed onset or progressive hearing loss
- Approximately 15% of children with hearing loss passed infant hearing screening
- Otitis media and other middle ear disorders are common in the pre-school population

Year 2007 Joint Committee on Infant Hearing (JCIH):
Risk Indicators for Delayed Onset or Progressive Hearing Loss

PEDIATRICS®

OFFICIAL JOURNAL OF THE AMERICAN ACADEMY OF PEDIATRICS

Year 2007 Position Statement: Principles and Guidelines for Early Hearing Detection and Intervention Programs

Joint Committee on Infant Hearing

Pediatrics 2007;120;898

DOI: 10.1542/peds.2007-2333

Year 2007 JCIH Position Statement: Risk Indicators Associated with Permanent Congenital, Delayed-Onset, or Progressive Hearing Loss in Childhood

- Delayed onset, late onset, or "acquired" hearing loss: Normal auditory function (hearing) at birth with the onset of auditory dysfunction (hearing loss) in infancy or early childhood
- Progressive hearing loss: Normal auditory function (hearing) at birth with the onset of auditory dysfunction (hearing loss) in infancy or early childhood

Increased Prevalence of Hearing Loss in School Age Children versus Newborn Infants

- Fortnum et al. (2001). *BMJ, 323*, 536-554
  - Prevalence within 17,160 children increased from 1% at age 3 years to 2% at age 9 to 16 years
  - Up to 50% of children with hearing loss at age 9 passed newborn hearing screening.
- Grote (2000). Neonatal screening for hearing impairment. *Lancet, 355*, 513-514
  - UNHS programs do not detect 10 to 20% of permanent hearing loss that begins later
- White (October 2010). ASHA Virtual Audiology Conference
  - Prevalence of 3/1000 for permanent hearing loss in infants increases to 9-10/1000 in school age children

The Important Role of Otoacoustic Emissions in Pre-School Hearing Screening

- Introduction to Early Hearing Detection and Intervention (EHDI)
- Guidelines for preschool hearing screening and limitations of pure tone screening
- Summary of research in support of OAEs in preschool hearing screening
- Evidence-based strategy for applying OAEs in preschool hearing screening
- Summary, questions & answers:

Guidelines for Preschool Hearing Screening and Limitations of Pure Tone Screening

- 1982 US Department of Health and Human Services, PHS
- 1984 American Academy of Pediatrics Policy Statement
- 1985 ASHA Guidelines for identification audiometry
- 1989 US Preventive Services Task Force
- 1989 American Public Health Association
- 1990 ASHA Guidelines for Screening of Hearing Impairment and Middle-Ear Disorders
- 1997 ASHA Guidelines for Audiologic Screening
- Current clinical guidelines will be discussed in a minute

Guidelines for Preschool Hearing Screening and Limitations of Pure Tone Screening

- ASHA Guidelines for Audiologic Screening (1997): Hearing screening of 7-month old through 2-year old children
  - "The panel concluded that for this age group, the development of screening guidelines to be used only by audiologists was appropriate and necessary."
  - For children who can be conditioned for play audiometry use earphones and screen at 20 dB HL for 1000, 2000, and 4000 Hz
  - For children who can be conditioned for VRA use earphones and screen at 30 dB HL for 1000, 2000, and 4000 Hz
  - Alternatives include screening in calibrated sound field for those children who do not accept earphones

Pre-School Pure Tone Hearing Screening
Questions to Ask About Research Studies

- Qualifications of persons performing hearing screening, e.g.,
  - Audiologist
  - Graduate student in audiology or speech pathology
  - Other health professional
  - Trained non-health professional
- Ambient noise levels in the test environment
- Screening protocol including
  - Earphone type (supra-aural versus insert)
  - Test frequencies
  - Response criteria
- How many children could not be tested (CNT)?
- What were the PASS and FAIL (did not pass) rates?

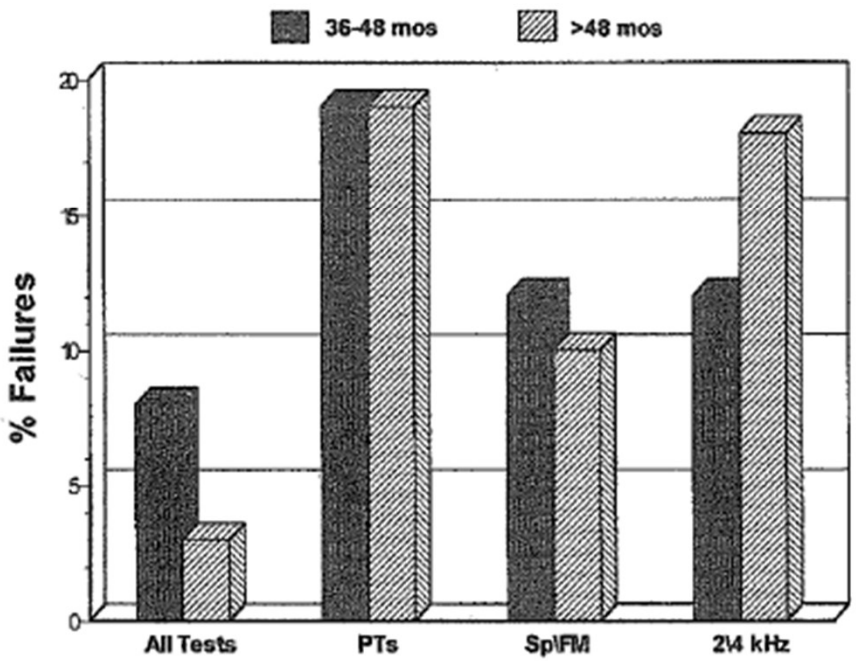
Behavioral Pre-School Hearing Screening: *Not Feasible for Young Preschool Children*

- Krishnamurti, Hawks & Gerling (1999). Performance of preschool children on two hearing screening protocols. *Contemporary Issues in Communication Science and Disorders, 26,* 63-68 [Kent State University]
  - Methods
    - ✓100 preschool children age 36 to 60 months
    - ✓Testing unsuccessful for additional 3 children
    - ✓Screening performed by audiology PhD student
    - ✓Settings were daycare centers … "moderate to high socioeconomic status"
    - ✓Hand raising response
    - ✓Protocol and ambient noise consistent with ASHA guidelines

Pure Tone Hearing Screening Failure Rate

(Krishnamurti, Hawks & Gerling, 1999)

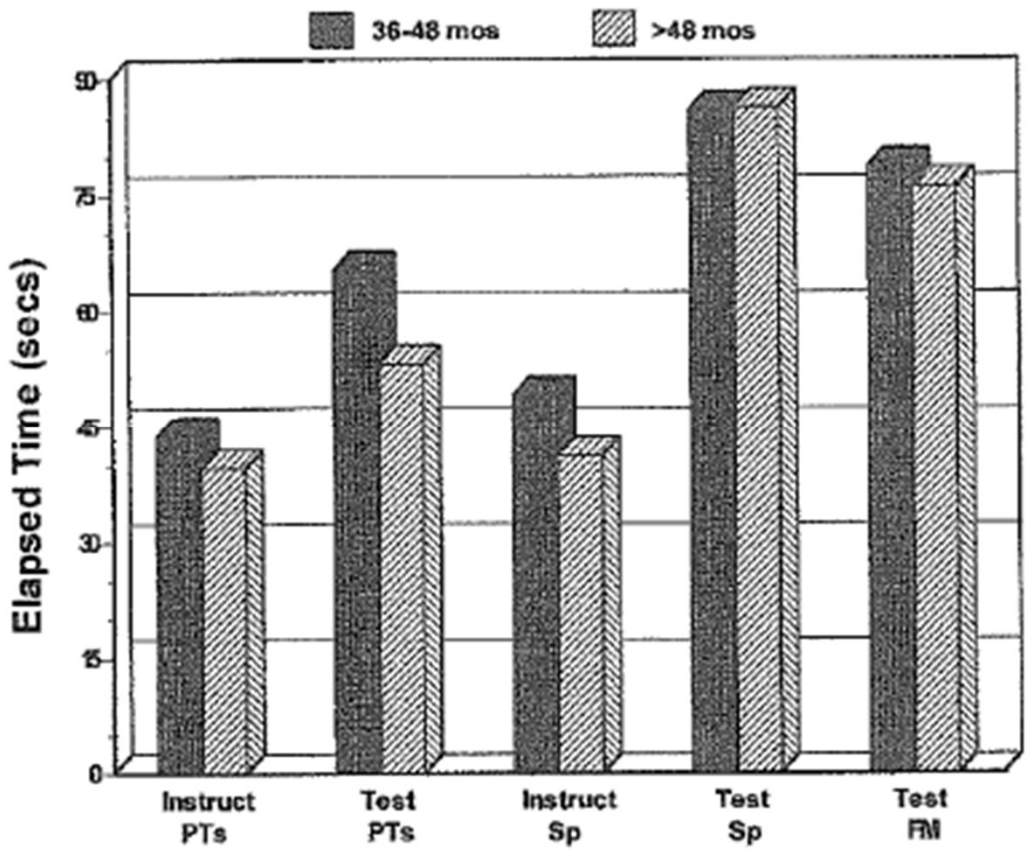
Figure 3. Percentage of screening failures by younger (36 to 48 months) and older (> 48 months) subjects for all tests (pure tone, spondee, and FM tone), pure tone (PTs), spondee and FM tone (Sp\FM), and 2 or 4 kHz pure tones.



Initial pure tone screening failure rate = 24%

Pure Tone Hearing Screening Test Time

(Krishnamurti, Hawks & Gerling, 1999)



Note: Not conditioned play audiometry

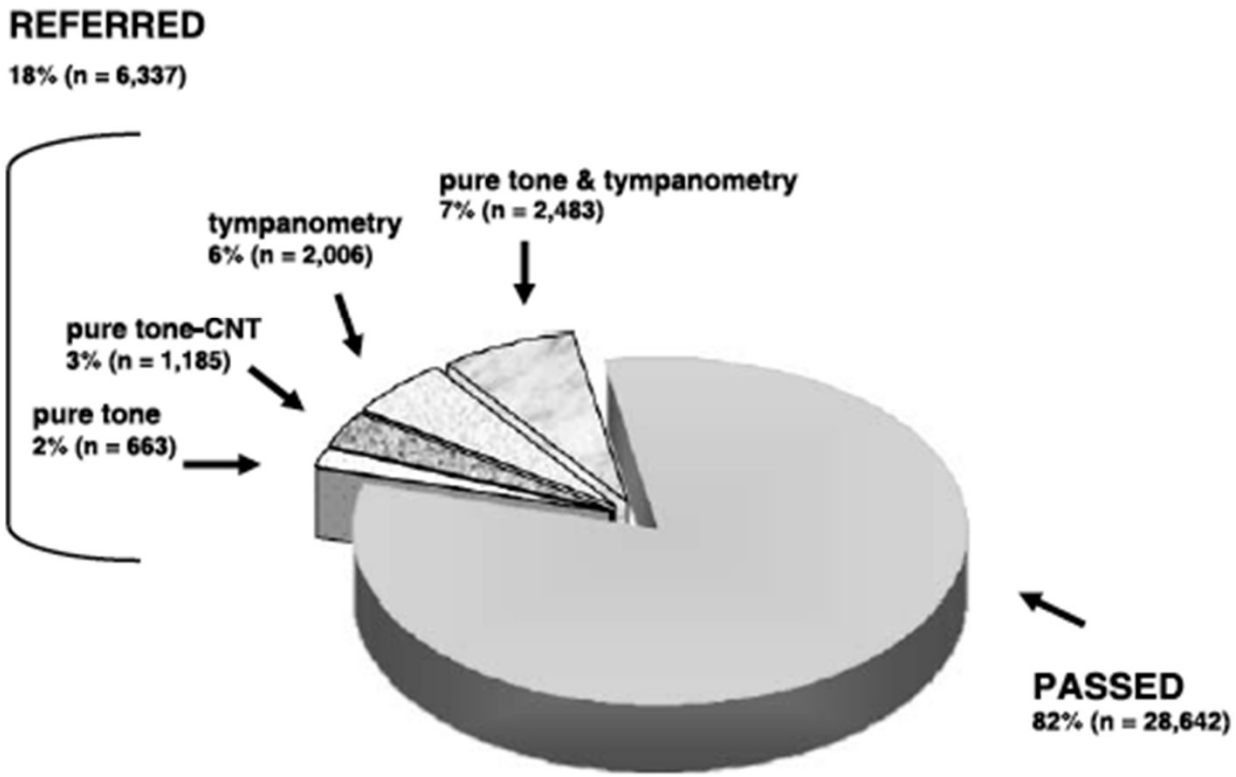
Behavioral Pre-School Hearing Screening in Public Pre-School, Day Care or Head Start Settings

- Serpanos YC & Jarmel F (2007). Quantitative and qualitative follow-up outcomes from a preschool auditory screening program: Perspectives over a decade. *American Journal of Audiology 16,* 4-12
  - 34,979 preschool children age 3 to 5 years
  - Settings were public pre-school, day care, or head start centers
  - Pure tone screening at 20 dB for 1000, 2000, 3000 & 4000 Hz
  - Audiology or SLP graduate students from 6 different academic programs in NYC and Long Island area performed screening
  - Hand raising response with CPA if CNT
  - "Difficult to test" children were screened by supervisor
  - Immediate rescreen of failures by supervising audiologist
  - Tympanometry after pure tone screening by supervisor

Evidence-Based Problems with Behavioral Pre-School Hearing Screening

Serpanos & Jarmel, 2007

Figure 1. Pass/refer pure-tone and tympanometry screening outcomes. Total number of children screened = 34,979. CNT = could not test.



Evidence-Based Problems with Behavioral Pre-School Hearing Screening:

Allen et al (2004)

- **Allen RL, Stuart A, Everett D & Elangovan S (2004). *American Journal of Audiology, 13*. 29-38**
  - **N = 1462 3 and 4 year old children in Head Start programs**
  - **Followed ASHA 1997 Guidelines for pure tone screening, tympanometry, plus stoscopy**
  - **54% passed initial screening with all three procedures**
  - **Pass rate for each procedure**
    - ✓**90% for otoscopy**
    - ✓**71% for tympanometry**
    - ✓**71% for pure tones (29% failure rate)**
  - **Rescreen pass rate was 76%**
  - **Only about 71% received recommended evaluation**
  - **Hearing status of 18% of the children never determined**

Behavioral Pre-School Hearing Screening in Physicians' Office Setting

- Halloran, Wall, Evans, Hardin & Woolley (2005). Hearing screening at well-child visits. *Arch Pediatr Adolesc Med, 159,* 949-955
  - N = 1061 children age 3 to 19 years
  - "Convenience sample" with medical insurance coverage
  - Eight pediatric practices in Alabama
    - ✓5 nonacademic (private) practices
    - ✓3 academically affiliated practices
  - Screening in examination room (trained research assistant)
  - 95% conventional screening and 5% play audiometry
  - PT screening at 20 dB HL for 1000, 2000, and 4000 Hz
  - Screening audiometers with supra-aural earphones

Behavioral Pre-School Hearing Screening Screening in Physicians' Office Setting

Halloran et al (2005)

- Completion of hearing screening
  - Age
    - ✓3 years: 55% (45% unable to complete screening)
    - ✓4 years: 93%
    - ✓5 years: 97%
    - ✓6 years: 100%
  - Pediatricians didn't refer the children) for
    - ✓59% of the children failing the screening
    - ✓73% of the children with CNT results

Behavioral Pre-School Hearing Screening Screening in Physicians' Office Setting … Follow Up Study

- Halloran, Hardin & Wall (2009). Validity of pure-tone hearing screening at well-child visits. *Arch Pediatr Adolesc Med, 163,* 158-163
  - Of the total of 1061 children undergoing hearing screening, a group of 130 children received complete audiological evaluation
  - "With audiologic evaluation used as the gold standard"
    - ✓Sensitivity was 50%
    - ✓Specificity was 78%
    - ✓None of the 28 children who could not be tested had hearing loss

Behavioral Pre-School Hearing Screening Screening in Physicians' Office Setting

Halloran et al (2005)

- "A national survey of general pediatricians found that guidelines were more likely to be followed if they were:
  - Simple
  - Feasible
  - And demonstrated improved outcomes"

Flores G, Leo M, Bauchner H & Kastner B (2000). Pediatrician's attitudes, beliefs, and practices regarding clinical practice guidelines: a national survey. *Pediatrics, 105*, 496-501

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- Evidence-based strategy for applying OAEs in preschool hearing screening
- Summary, questions & answers:

Summary of Research in Support of OAEs in Preschool Hearing Screening

- Ho et al (2002). Otoacoustic emissions and tympanometry screening among 0-5 year olds. Laryngoscope, 112, 513-519
- Eisermann et al (2007). Using otoacoustic emissions to screen for hearing loss in early childhood care settings*. Int J Pedi ORL, 72,* 475-482
- Hunter et al (2007). Hearing screening and middle ear measures in American Indian infants and toddlers. *Int J P ORL, 71,* 1429-1438
- Bhatia et al (2013). Early identification of young children with hearing loss in Federally qualified health centers. *J Developmental Behavioral Pediatrics, 34,* 15-21
- Kreisman et al (2013). Preschool hearing screenings: Comparison of distortion product otoacoustic emission and pure-tone protocols. J Educational Audiology, 19, 48-57

Summary of Research in Support of OAEs in Preschool Hearing Screening

- Kreisman BM, Bevilacqua E, Day K, Kreisman NV & Hall JW III (2013). Preschool hearing screenings: Comparison of distortion product otoacoustic emission and pure-tone protocols. *Journal of Educational Audiology, 19*, 48-57
- Methods
  - 198 preschool children age 3 to 6 years (mean 4.5 years)
  - Testing unsuccessful for another 2 children (PTs only)
  - Screening procedures
    - ✓DPOAEs
    - ✓PT screening with conditioned play (block in bucket)
  - Data collected by audiology and SLP grad students in 8 different preschool facilities
  - Protocol consistent with ASHA 1997 guidelines

Hearing Screening Time for DPOAEs versus Pure Tone Technique in Pre-School Children

(Kreisman et al, 2013)

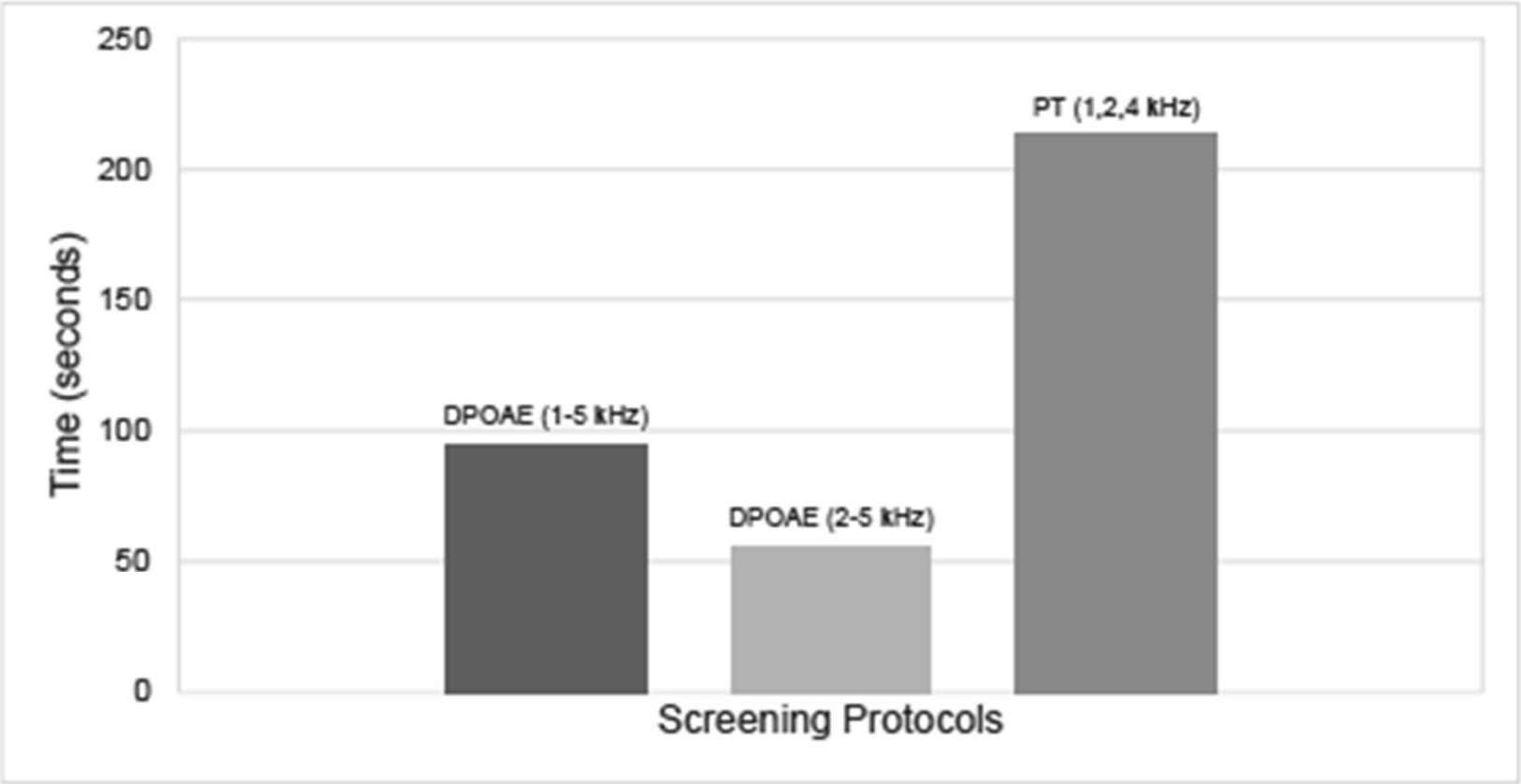

Figure 1. Mean time to complete each screening protocol.

Hearing Screening Pass/Fail Data for DPOAEs versus Pure Tone Technique in Pre-School Children

(Kreisman et al, 2013)

Table 2. Pass/Fail Rates for DPOAE (1-5 kHz), DPOAE (2-5 kHz) and Pure-Tone (1,2,4 kHz) Protocols

Protocol	Pass	Fail	Total
DPOAE (1-5 kHz)	134	64	198
DPOAE (2-5 kHz)	141	57	198
Pure-Tone (1,2,4 kHz)	175	21	196

Note. DPOAE=Distortion Product Otoacoustic Emissions. Two children would not cooperate to be screened using pure tones.

Summary of Research in Support of OAEs in Preschool Hearing Screening: *Advantages of OAEs*

- Objective and not dependent on child's
  - Behavioral response
  - Cognition
  - Language level or native language
- Painless and even no discomfort
- Reliable
- Efficient and quick to administer (< 4 minutes)
- Simple to administer with low level of technical skill …Does not require an audiologist
- Measurement doesn't require acoustically treated environment
- Hand-held and portable equipment
- Test outcome is documented electronically or in printout

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The Important Role of Otoacoustic Emissions in Pre-School Hearing Screening: *New Strategy Using OAEs, Tympanometry, and Acoustic Reflexes*

The Important Role of OAEs in Pre-School Hearing Screening: *Combining OAEs, Tympanometry, and Acoustic Reflexes*

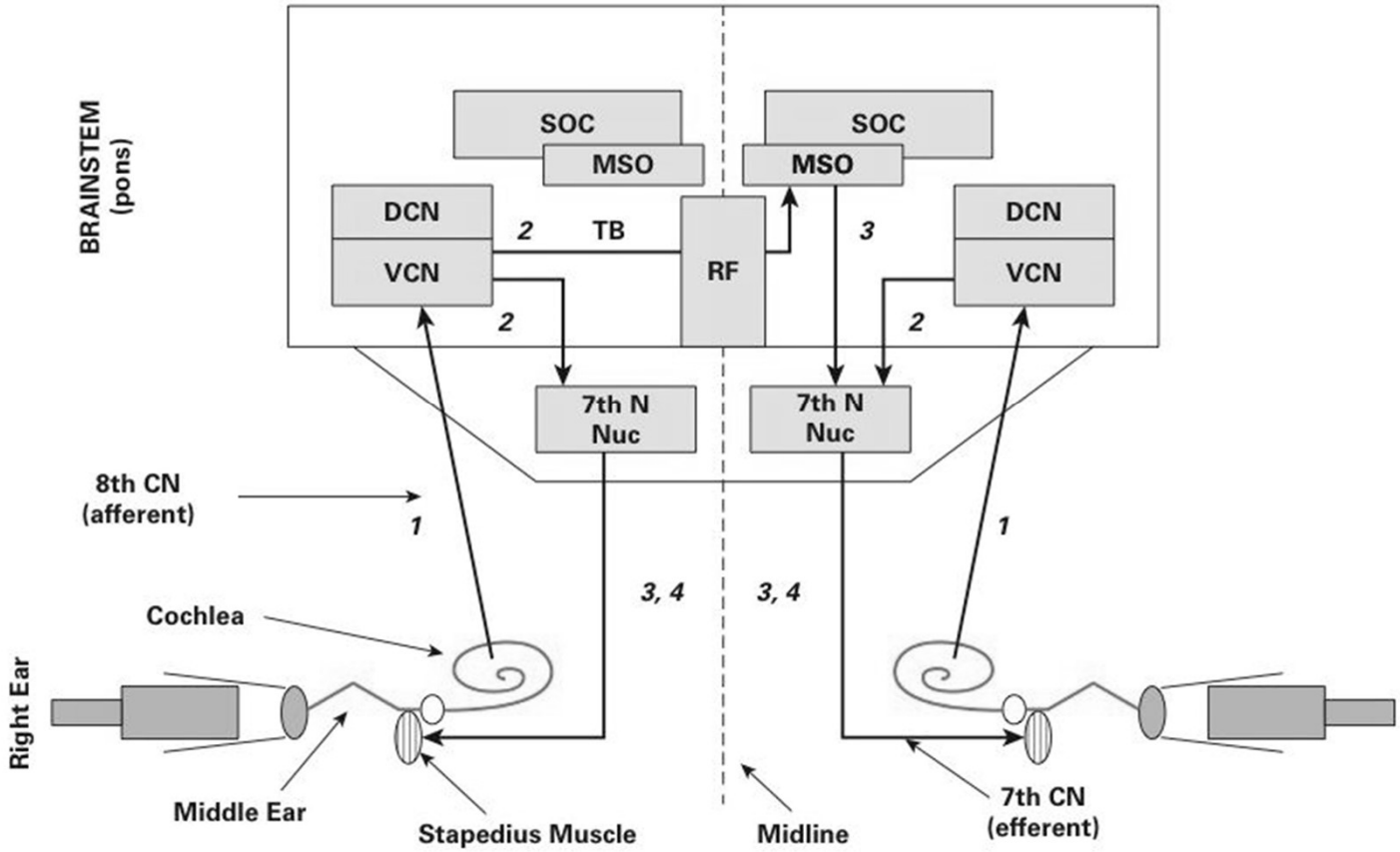
- Objective and not dependent on child's behavioral response, cognition, developmental age, or language level
- Reliable
- Efficient and quick to administer (< 4 minutes)
- Simple to administer with low level of technical skill
- Does not require an audiologist
- Does not require an acoustically treated test environment
- Hand-held and portable equipment
- Test outcome is documented electronically or in printout
- Sensitive measure of
  - Middle ear function
  - Cochlear (outer and inner hair cell) function
  - ANSD

Year 2007 Joint Committee on Infant Hearing (JCIH): *Protocol for Evaluation of Hearing Loss In Infants from Birth to 6 months*

- ❑ Child and family history
- ❑ Evaluation of risk factors for congenital hearing loss
- ❑ Parental report of infant's responses to sound
- ❑ Clinical observation of infant's auditory behavior
- ❑ Audiological assessment
  - Auditory brainstem response (ABR)
  - Otoacoustic emissions (distortion product or transient OAEs)
  - Tympanometry with 1000 Hz probe tone
  - Supplemental procedures, e.g.,
    - ✓ Electrocochleography (ECochG)
    - ✓ Auditory steady state response (ASSR)
    - ✓ Acoustic reflex measurement (for 1000 Hz probe tone)

Acoustic Stapedial Reflex Pathways According to Erick Borg

From Hall JW III (2014). Introduction to Audiology Today. Boston: Pearson



The Important Role of Otoacoustic Emissions in Pre-School Hearing Screening: *Acoustic Reflexes in Neonates*

- Kei J. Acoustic stapedial reflexes in healthy neonates: normative data and test-retest reliability. *JAAA, 23,* 2012
  - 66 full term infants
  - Acoustic reflexes recorded with 1000 Hz probe tone
  - Tone and BBN stimuli
  - All neonates had acoustic reflexes

Acoustic Reflexes in Neonates

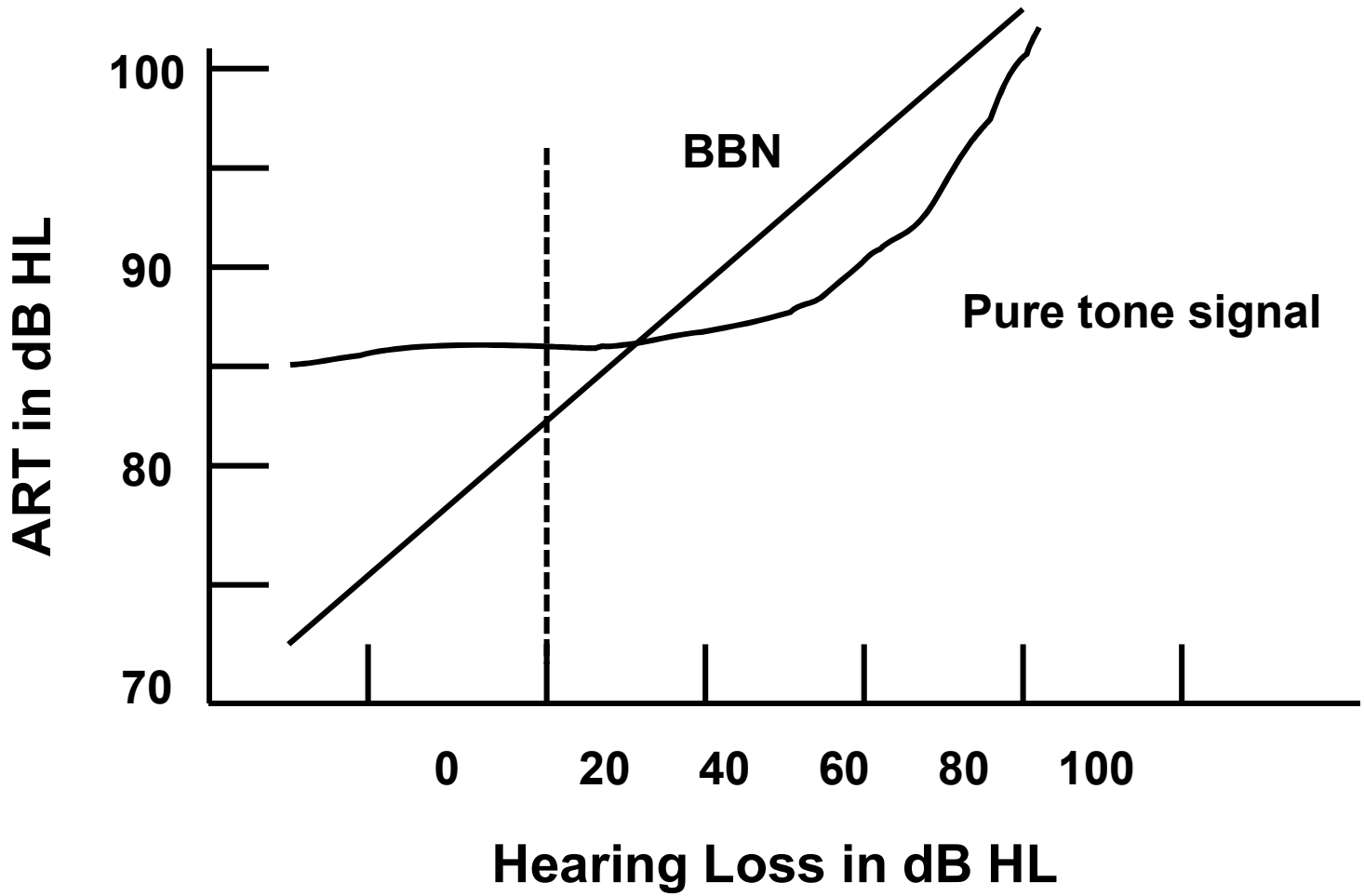
(Kei J. Acoustic stapedial reflexes in healthy neonates: normative data* and test-retest reliability. *JAAA, 23,* 2012)

Stimulus	Median ART (dB HL)	90% Range
500 Hz	80	70 - 95
2000 Hz	70	60 - 85
4000 Hz	65	50 - 80
BBN	55	50 – 75

** N = 68 ears*

Simplified SPAR (Sensitivity Prediction by the Acoustic Reflex)

Hall JW III, Berry GA and Olson K. Identification of serious hearing loss with acoustic reflex data: Clinical experience with some new guidelines. Scandinavian Audiology 11: 251-255, 1982



The Important Role of Otoacoustic Emissions in Pre-School Hearing Screening: *A New Feasible and Evidence-Based Approach*

Birth to 4 Years

DPOAES
- **L1 = 65 dB; L2 = 55 dB**
- **2000 – 5000 Hz**
- **PASS = DP ≥ 0 dB SPL**

Fail?
- **Immittance measures**
  - **Tympanometry**
  - **ART for BBN**
  - **PASS = type A; BBN < 80 dB)**

Otoscopy as indicated

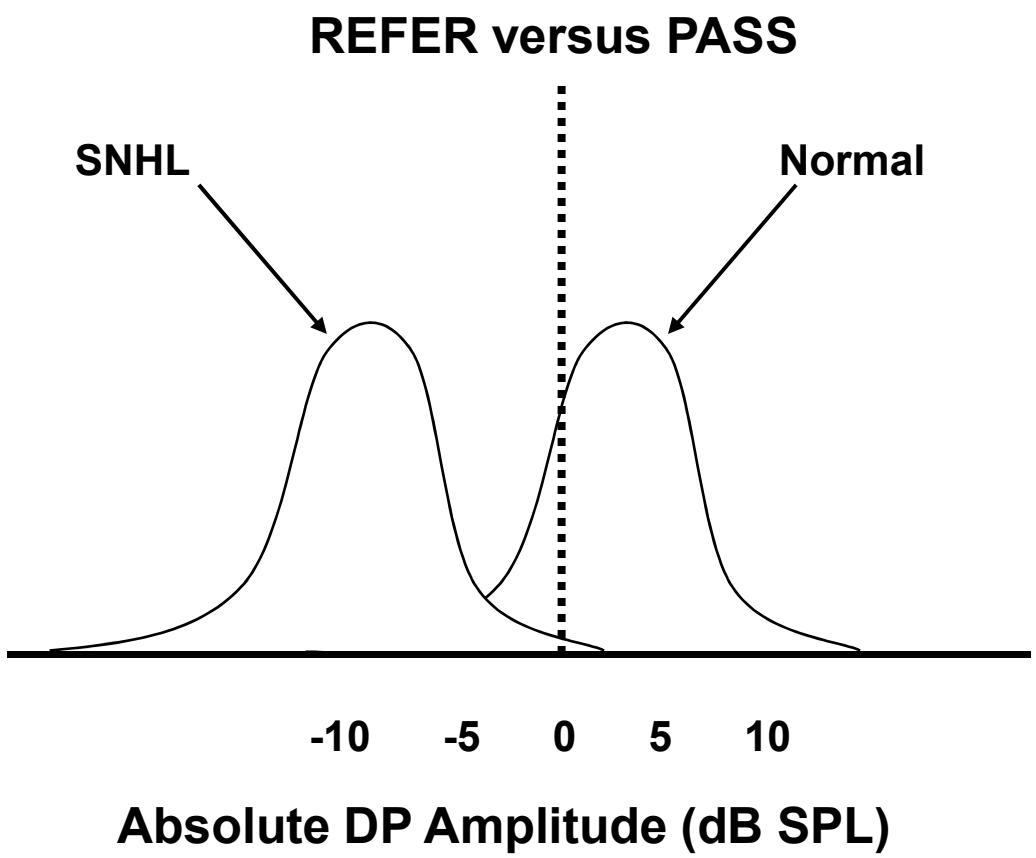
≥ 4 Years

Pure tone screening at 20 dB *or* PASS for previous hearing screening? Follow birth to 4 year objective test protocol.

Previous FAIL outcome or no documented hearing screening? Follow 2011 AAA Guidelines (Pure tone screening at 20 dB HL)

OAE Screening in Pre-School and School Age Children: Criterion for PASS versus REFER

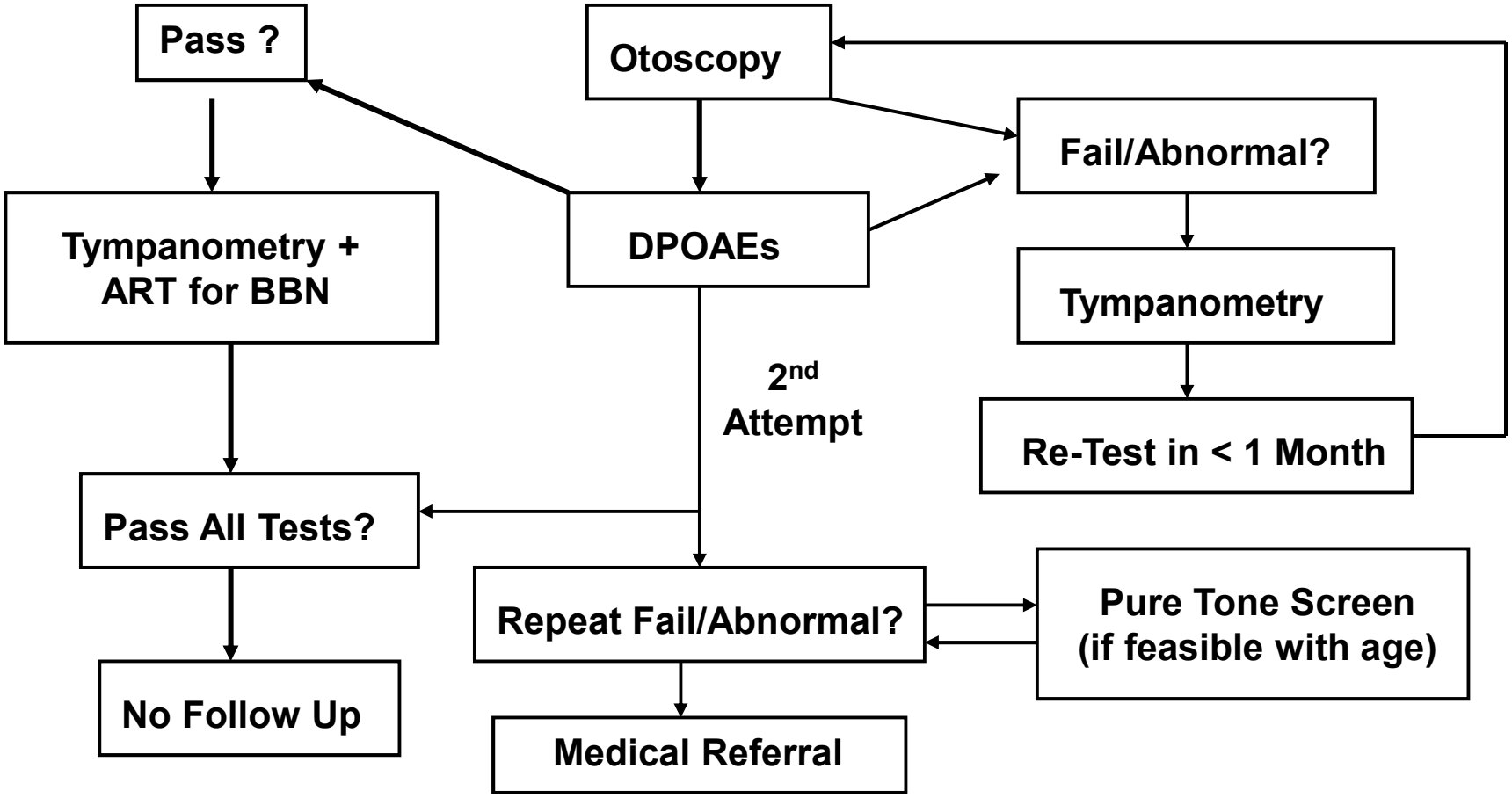
(Data for adults and older children from Gorga, Stover & Neely, 1996)



Creating a Preschool DPOAE Screening Protocol
(GSI Corti)

Options	Protocol Name	Number of Frequencies	Frequencies	Average Time	Allow Changes	Pass Criteria
DP Diagnostic	DP 1.5-6.0	6	1.5,2,3,4,5,6	4 sec	Yes	Optional
	DP 1.6-8.0	12	1.6,2,2.5,3.2,3.6,4,4.5,5,5.6,6,6.3,7.1,8	4 sec	Yes	Optional
	DP 1.5-12	12	1.5,2,3,4,5,6,78,9,10,11,12	4 sec	Yes	Optional
	DP 2.0-5.0	4	2,3,4,5	4 sec	Yes	Optional
	DP 4S	4	2,3,4,5	4 sec	No	Yes

New Strategy for Pre-School Hearing Screening with OAEs, Tympanometry, and Acoustic Reflexes



The Important Role of Otoacoustic Emissions in Pre-School Hearing Screening: *Summary, Questions & Answers*

- Preschool hearing screening is essential for successful EHDI
- Pure tone technique is not feasible for young preschool children
- OAEs offer an evidence-based technique for preschool hearing screening
- OAEs in combination with aural immittance measures permit on site follow-up assessment for children failing preschool screening

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Effective And Efficient Pre-School Hearing Screening: Essential For Successful Early Hearing Detection And Intervention (EHDI)

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Abstract

An unacceptable number of infants failing newborn hearing screening do not receive necessary follow-up services in a timely fashion as a result of loss to follow-up problems. In addition, a high proportion of children who pass newborn hearing screening later acquire hearing loss during the preschool years. Systematic pre-school hearing screening offers a logical strategy for detection of hearing loss among these children.

Pure tone hearing screening of older preschool children has questionable test performance and validity. And, there is consensus that a behavioral technique is not feasible for routine hearing screening of younger preschool children. Otoacoustic emissions (OAEs) offer the most promising option for systematic hearing screening of the preschool population. Multiple advantages of OAEs are cited in support of their role in preschool hearing screening. This paper summarizes a new evidence-based and clinically feasible strategy for effective and efficient preschool hearing screening that relies on objective auditory tests.