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Combined OAE and AABR Approach for Newborn Hearing Screening

Presenter: James W. Hall III, Ph.D.

Moderator: Carolyn Smaka, AuD, Editor in Chief, AudiologyOnline

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Combined OAE and AABR Approach for Newborn Hearing Screening

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Combined OAE and AABR Approach for Newborn Hearing Screening

- **Learner Outcomes:** ***As a result of this Continuing Education Activity, participants will be able to …***
  - **Identify 3 advantages of using a combined OAE/AABR hearing screening approach.**
  - **Cite a clinical guideline that recommends combined OAE/AABR hearing screening.**
  - **Describe how OAE and AABR techniques are used in well baby versus NICU infants.**

Combined OAE and AABR Approach for Newborn Hearing Screening

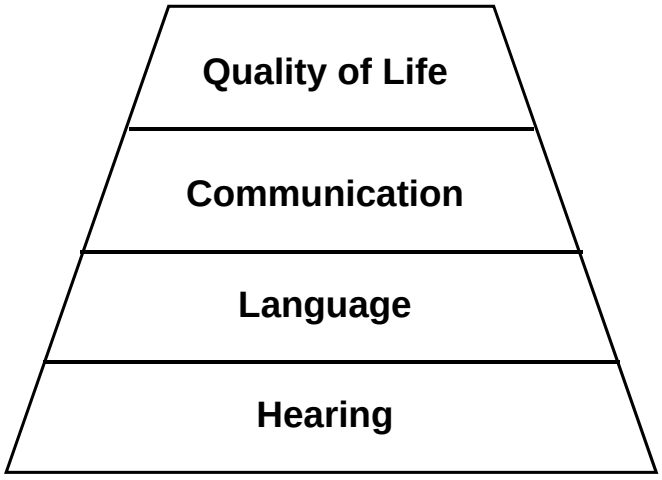
- **Introduction**
- **Brief historical overview**
- **Rationale for combined OAE and AABR strategy**
- **Review of literature**
- **Guidelines for clinical implementation of combined OAE and AABR strategy**
- **Summary, questions, answers**

Early Hearing Loss Detection and Intervention (EHDI): Focusing on the Goal, Not the Process

Identification → **Diagnosis** → **Intervention** → **Outcome**

- **Identification**
  - Screening
  - History
  - Parent-Referral
  - Professional referral
- **Diagnosis**
  - Hearing loss
  - SNHL
  - CHL
  - Unilateral
  - ANSD
  - APD
  - Vestibular disorder
- **Intervention**
  - Hearing aids
  - Aural Rehab
  - Counseling
  - Cochlear implant (s)
  - Vestibular rehab
  - Drugs
  - Surgery
- **Outcome**
  - Effective communication
  - Efficient communication
  - Academic success
  - Financial independence
  - Quality of life

Hearing: An Important Building Block in the Foundation for Quality of Life



UNHS HISTORICAL PERSPECTIVE: Early work by Marion Downs

- Froding CA. (1960). Acoustic investigation of newborn infants. Acta Otolaryngol 52: 31-41 *(aural-palpebral response)*
- Downs MP, Sterritt GM. (1964). Identification audiometry for neonates: A preliminary report. J Auditory Res 4: 69-80. *(APR, startle, and behavioral responses to 3000 Hz narrow band stimulus)*
- Downs MP, Sterritt GM. (1967) A guide to newborn and infant hearing screening programs. Arch Otolaryngol 85: 37-44.
- Downs MP, Hemenway WG. (1969). Report on the hearing screening of 17,000 neonates. Int'l Audiology 8: 72-76. *(study led to formation of first Joint Committee on Infant Hearing in 1969)*

1982 Joint Committee on Infant Hearing Newborn Risk Factors for Hearing Loss

- Family history of childhood hearing loss
- Congenital infection associated with hearing loss, e.g., cytomegalovirus (CMV), herpes, syphilis, rubella
- Bacterial meningitis
- Craniofacial anomalies (morphologic abnormalities of the ear)
- Low birth weight (< 1500 grams)
- Hyperbilirubinemia (requiring exchange transfusion)
- Aphyxia (APGAR scores of 0 – 3 at five minutes)

Universal Newborn Hearing Screening: Rationale … Average Ages in Months for intervention

Hearing Loss	Suspicion	Dx	HA fitting	Intervention
No Risk Factor				
Mild/moderate	**15**	**22**	**28**	**28**
Severe/profound	**8**	**13**	**16**	**16**
Known Risk Factor				
Mild/moderate	**8**	**12**	**22**	**28**
Severe/profound	**7**	**12**	**15**	**16**

Harrison & Roush, 1996

Rationale for UNHS: Prevalence of Infant Hearing Loss in the U.S.A.

Category	Births Annually	Prevalence	Total Hearing Loss
Healthy	**3,600,000**	**3/1000**	**10,800**
At-risk	**400,000**	**30/1000**	**12,000**
Total	**4,000,000**	**5.7/1000**	**22,800**

Northern & Hayes, 1994

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Marion Downs (1914-2014)

"Mother of Newborn Hearing Screening, Pediatric Audiology, and Founder of JCIH"

Universal Newborn Hearing Screening: Turning Point in the United States of America

- Evidence in support of benefits of early identification on speech and language development (for pediatricians)
- Recognition of economic consequences of hearing loss (by policy makers)
- Emergence of technology for automated auditory brainstem response (ABR) and otocoustic emissions (OAEs)
- Evidence of low failure rates (< 4%) and automated ABR and OAE techniques
- Relatively low cost of identifying infants with hearing loss versus expense of intervention with later identification

Universal Newborn Hearing Screening: Endorsed in the *1994 JCIH Position Statement*

- "Hearing loss of 30dB HL and greater in the frequency region important for speech recognition will interfere with the normal development of speech and language.
- "Techniques used to assess hearing of infants must be capable of detecting hearing loss of this degree in infants by age three months and younger.
- Of the various approaches to newborn hearing assessment currently available, two physiologic measures...auditory brainstem response (ABR) and otoacoustic emissions (OAE)...show good promise for achieving this goal"

Joint Committee on Infant Hearing 1994 Position Statement

Christie Yoshinaga-Itano, PhD
Yoshinago-Itano et al (Univ. of Colorado). Pediatrics 102 (5): 1161-1171, 1998.

Language of Early and Later Identified Children with Hearing Loss

- **Yoshinago-Itano et al (Univ. of Colorado). Pediatrics 102 (5): 1161-1171, 1998.**
  - **N = 72 children with HL identified by 6 months and N = 78 children identified later**
  - **all children received intervention services with 2 months of identification**
  - **Conclusion: "Significantly better language development was associated with early ID of hearing loss and early intervention . . . the language advantage was found across all . . . degrees of hearing loss."**

American Academy of Pediatrics (AAP) Committee on Newborn and Infant Hearing Loss: Detection and Intervention

- **Pediatrics 103 (2): 527-529, 1999 (February)**
- **Screening**
- **Tracking & Followup**
- **Evaluation**
- **Abstract:** *"This statement endorses the implementation of universal newborn hearing screening. In addition, the statement reviews the primary objectives, important components, and recommended screening parameters that characterize an effective universal newborn hearing screening program."*

UNHS: National Legislation in the United States

- **EHDI grants were first authorized in the Newborn Infant Hearing Screening and Intervention Act of 1999**
  - **Provided federal funds to develop infant hearing screening and intervention programs**
  - **Congress reauthorized the grants through the Children's Health Act of 2000 (PL 106-310)**
  - **Included provisions for**
    - ✓**Early hearing screening and evaluation of all newborns**
    - ✓**Coordinated intervention**
    - ✓**Rehabilitation services**
    - ✓**Research**

Combined OAE and AABR Approach for Newborn Hearing Screening

- Introduction
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- Rationale for combined OAE and AABR strategy
  - Background on AABR
  - Background on OAEs
- Review of literature
- Guidelines for clinical implementation of combined OAE and AABR strategy
- Summary, questions, answers

The First Comprehensive Description of the Auditory Brainstem Response (ABR) in Humans

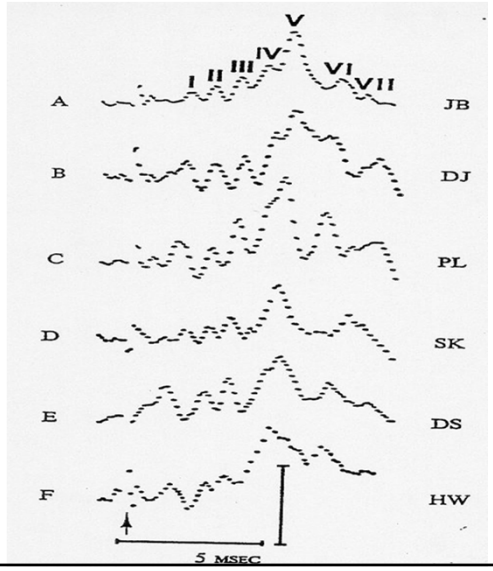
Jewett D and Williston J.

Auditory evoked far fields averaged from the scalp of humans.

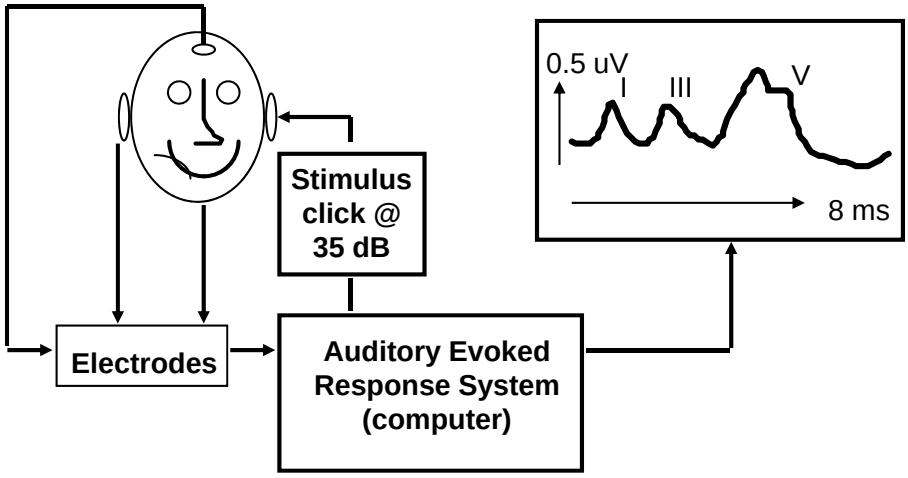
Brain 4: 681-696, 1971.

Don Jewett

Jewett & Williston, 1971
Normal Subject Waveform Consistency … the Ideal Clinical Tool



Newborn Hearing Screening: Auditory Brainstem Response (ABR)



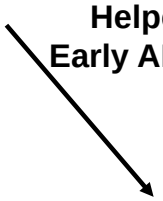
Robert Galambos, MD, PhD

Director of the Laboratory (Yale University) Where the ABR was "Discovered" and Pioneer of Early Pediatric Applications of ABR

- **1974: Hecox KE & Galambos R. Brain stem auditory evoked responses in human infants and adults. *Archives of Otolaryngology 99.***
- **1975: Schulman-Galambos C. & Galambos R. Brain stem evoked responses in premature infants. *JSHR 18*.**
- **1979: Schulman-Galambos C. & Galambos R. Brain stem evoked response audiometry in newborn hearing screening. *Archives of Otolaryngology 105*:**

James Jerger, Ph.D.
"Father of Diagnostic Audiology"
Baylor College of Medicine and Methodist Hospital, Houston TX

Larry Mauldin Circa 1975
Helped Build
Early AER System

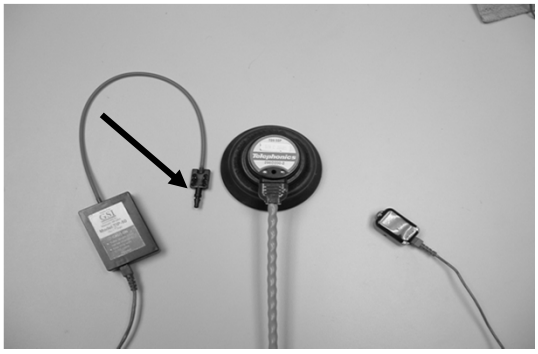


Newborn Hearing Screening of At Risk Infants by Audiologists in the 1980s

AABR Test Protocol: Recording Parameters

Parameter	Selection	Rationale
Transducer	ER-3A inserts or custom earphones	Numerous infant advantages
Type	Clicks or chirp clicks	Available on all systems
Duration	0.1 ms	Synchronous firing of auditory fibers
Rate of stimulation	> 30/second	Faster rate = shorter test time
Electrode type	Disposable or custom	Minimize risk of infection
Electrode sites	Fz-Ai or Fz-Nape	Nape = larger wave V
Filter settings	30 – 3000 Hz	Low frequency infant ABR spectrum

ABR Transducer Options for Pediatric ABR Recordings: *Insert Earphone with Adaptor*



UNHS WITH AUTOMATED AABR: A MULTI-SITE INVESTIGATION
J Perinatology 20 ((8): S128, December 2000.

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NEWBORN HEARING SCREENING WITH AABR
(N = 11,711)

SITE	NURSERY	N	SCREENERS	TIME OF SCREEN
Boulder	WBN	1228	volunteers	22 hrs
Louisville	WBN	6061	nurses	28 hrs
Memphis	WBN	1563	technicians	19
Huntsville	WBN	2071	audiologists	24
Nashville	ICN	788	audiologists nurses grad students	- - -

NEWBORN HEARING SCREENING WITH AABR
Test Performance and Outcome

SITE	WBN	ICN		Refer % D/C	Refer Lost F/U	False Pos
Boulder	**98%**	**2%**		**2%**	**16%**	**2%**
Louisville	**>99%**	**<1%**		**1%**	**45%**	**.35%**
Memphis	**>99%**	**N=1**		**3%**	**13%**	**2.5%**
Huntsville	**93%**	**7%**		**1%**	**21%**	**.05%**
Nashville	**0%**	**100%**		**6%**	**32%**	**2%**
N = 11,711				**2%**	**28%**	**0.9%**
			AAP	**≤ 4%**	**< 5%**	**< 2%**

Newer AABR Technology:
Chirp Stimuli and No “Disposables” (Maico MB-11)

ABR in Infant Hearing Screening: *The Research Continues*

- Stevens et al (2013). ABR in newborns: Effects of electrode configuration, stimulus rate, and EEG rejection levels on test efficiency. *Int J Audiol, 52,* 706-712
- Liu & Liu (2013). Hearing screening and diagnosis in a large sample of infants in central China. *J Med Screen, 20*, 21-26 (N = 11,894)
- Vinodh et al (2014) Reversibility of brainstem evoked response audiometry abnormalities at 3 months in term newborns with hyperbilirubinemia. *Indian Pediatr, 51*, 134-135 (India)
- Jiang & Wilkinson (2014). Impaired function of the ABR in term neonates with hyperbilirubinemia. *Brain Dev, 36*, 212-218 (China)

:

ABR in Infant Hearing Screening: *Chirp Stimuli*

- Cebulla & Shehata-Dieler (2012). ABR-based newborn hearing screening with MB11 BERAphone using an optimized chirp for acoustical stimulation. *Int J Pedi ORL, 76*, 536-543 (N = 6866)
- Rodrigues et al (2013). Comparing auditory brainstem response to tone burst and narrow band CE-chirp in young infants. *Int J Pedi ORL, 77*, 1565-60 (Brazil) Stuart & Cobb (2014). Effect of stimulus and number of sweeps on the neonate ABR. *Ear Hear, 35*, 585-588 [chirp]
- Xu et al (2014). Prediction of frequency-specific hearing threshold using chirp ABR in infants with hearing losses. Int *J Pedi ORL, 78,* 812-816

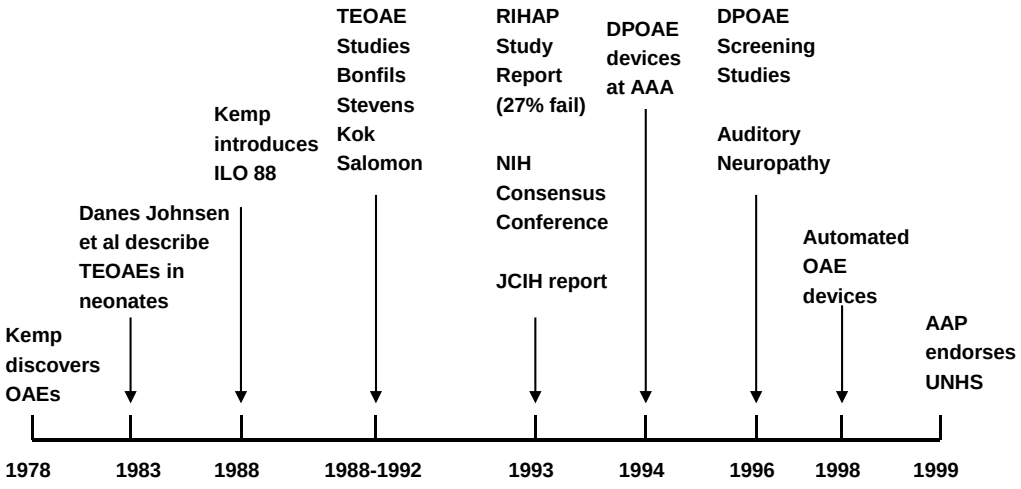
:

ABR in Infant Hearing Screening: *Minimizing False-Positive Errors*

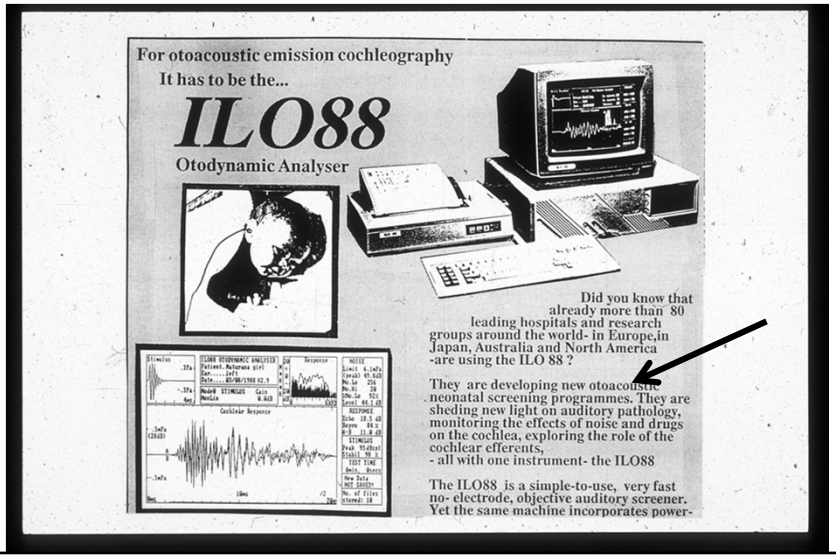
- **Clemens & Davis (2001). Minimizing false-positives in UNHS: A simple solution. *Pediatrics, 107.***
  - **Published false-positive rates are between 2.5 – 8%**
  - **Concerns about high false-positive rates include:**
    - ✓**Emotional trauma for parents**
    - ✓**Inappropriate disease labeling**
    - ✓**"Iatrogenesis" from unnecessary testing**
    - ✓**Increased expense … time and money**
  - **N = 3142 well babies screened with AABR**
  - **80% of babies who failed initial screening passed rescreen**
  - **At 2nd screening false-positives decreased from 3.9% to 0.8%**

Combined OAE and AABR Approach for Newborn Hearing Screening: OAE Technology

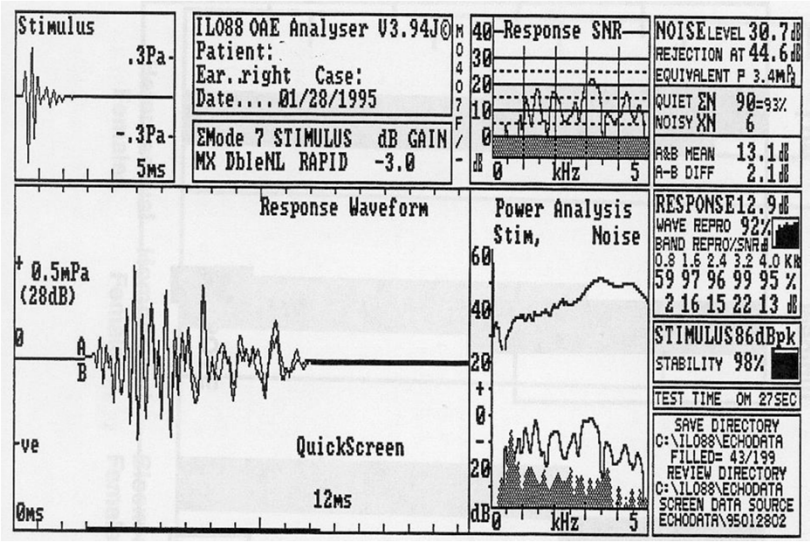
Newborn Hearing Screening with OAEs: Historical Perspective



Newborn Hearing Screening with Otoacoustic Emissions (OAEs)



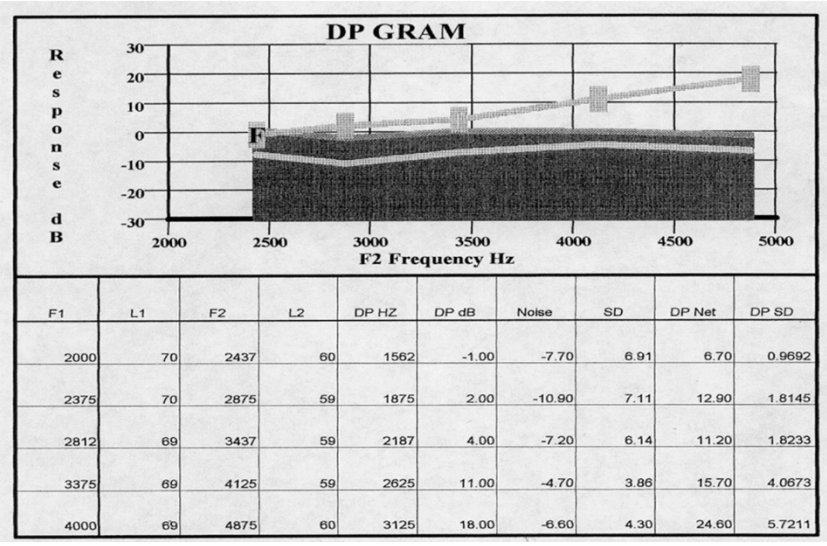
Newborn Hearing Screening with TEOAEs
(Otodynamics ILO 88)



Validation of Universal Newborn Hearing Screening with OAEs

- **Vohr et al. The Rhode Island Hearing Assessment Program: Experience with statewide hearing screening (1993-1996). Journal of Pediatrics 133: 353-357, 1998**
  - **53,121 babies underwent screening (NICU =5130)**
  - **Average initial failure rate = 10%**
  - **Failure rate for rescreens at 2 to 6 weeks = 14.7%**
  - **Over failure (refer) rate = 1.2%**
  - **111 infants identified with permanent hearing loss**
  - **Average age of intervention (amplification) = 5.7 months**

Newborn Hearing Screening with DPOAEs
(> 500 Peer Reviewed Published Papers)



F1	L1	F2	L2	DP HZ	DP dB	Noise	SD	DP Net	DP SD
2000	70	2437	60	1562	-1.00	-7.70	6.91	6.70	0.9692
2375	70	2875	59	1875	2.00	-10.90	7.11	12.90	1.8145
2812	69	3437	59	2187	4.00	-7.20	6.14	11.20	1.8233
3375	69	4125	59	2625	11.00	-4.70	3.86	15.70	4.0673
4000	69	4875	60	3125	18.00	-6.60	4.30	24.60	5.7211

Combined OAE and AABR Approach for Newborn Hearing Screening

- ❑ Introduction
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Combined OAE and AABR Approach for Newborn Hearing Screening

J Am Acad Audiol 15:414–425 (2004)

Newborn Hearing Screening with Combined Otoacoustic Emissions and Auditory Brainstem Responses

James W. Hall III*
Steven D. Smith†
Gerald R. Popelka* ** ††

Abstract

Accurate assessment of neonatal hearing screening performance is impossible without knowledge of the true status of hearing, a prohibitive requirement that necessitates a complete diagnostic evaluation on all babies screened. The purpose of this study was to circumvent this limitation by integrating two types of screening measures obtained near simultaneously on every baby.

Combined Automated OAE and ABR Technique
AUDIOscreener (GSI)

Combination OAE/AABR Study: Subjects

- N = 300 infants (600 ears)
- All babies underwent OAE and ABR screening
- Newborns that failed first DPOAE or ABR were re-screened prior to discharge
- Newborns discharged with 'refer' result returned within 2 to 3 weeks for follow-up diagnostic audiologic evaluation

Combination OAE/ABR Screening: Differentiation of Peripheral Auditory Dysfunction

(Hall, Smith & Popelka. Journal of the American Academy of Audiology, August 2004)

Type of dysfunction	OAE	ABR
None	Normal	Normal
External/middle ear *	Abnormal	Normal
Sensory (OHC)	Abnormal	Abnormal
Neural	Normal	Abnormal

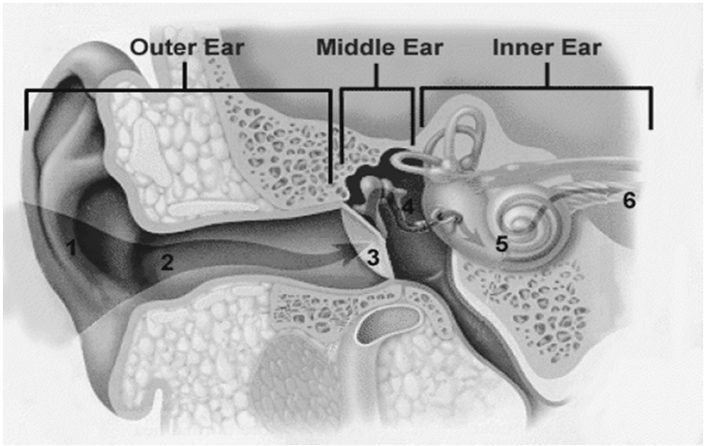
** Minor dysfunction in most cases*

Advantages and Disadvantages of AABR versus OAE for Infant Hearing Screening

	Advantages	Disadvantages
OAE	No electrodes	Affected by vernix
	Inexpensive	Failure rate higher < 24 hours
	No "disposables"	Affected by ambient noise
	Generally quick	Affected by middle ear disorder
	Detects OHC dysfunction	Normal in ANSD
AABR	Low failure rate < 24 hours	Electrode placement
	Detects ANSD	"Disposables" may add cost
	Higher reimbursement	Test time may be longer

Potential Sites of Auditory System Abnormality

- **Blockage**
- **Dysfunction**
- **Abnormal development**
- **Abnormal structure**



•Conductive •Sensory •Neural •Mixed

Combined OAE and AABR Study: Results (N = 600)

(Hall, Smith & Popelka. JAAA, August 2004)

		Screening Outcome		
Diagnostic Outcome		Pass	Refer	N
Normal		590	2	592
Hearing Impaired		0	8	8
	N	590	10	

Sensitivity = 100.0% Refer Rate = 1.7%

Specificity = 99.7% Positive Predictive Value = 80.0%

OAE and AABR Screening Techniques: *Additional Literature*

- Johnson, White, Widen, Gravel, James, Kennalley, Maxon, Sullivan-Mahoney, Voh, Weirather & Holstrum (2005). A multicenter evaluation of how many infants with permanent hearing loss pass a two-state otoacoustic emissions/automated auditory brainstem response newborn hearing screening protocol. *Pediatrics, 116,* 663-672
  - "If all infants were screened for hearing loss using the 2-stage OAE/A-ABR newborn hearing screening protocol currently used in many hospitals, then approximately 23% of those with PHL at approximately 9 months of age would have passed the A-ABR. This happens in part because much of the A-ABR screening equipment in current use was designed to identify infants with moderate or greater hearing loss."

OAE and AABR Screening Techniques: *Additional Literature*

- **Tobe et al (2013). Cost effectiveness analysis of a national neonatal hearing screening program in China: Conditions for the scale-up. PLoS One, 8**
  - **Based on the cost-effectiveness and potential health outcomes, the optimal path for scale-up would be to start with targeted OAE and then expand to universal OAE and universal OAE plus AABR.**
- **Kumar et al (2015). Hearing screening in a tertiary care hospital in India. Journal of Clinical Diagnostic Research, 9**
  - **"OAE and ABR screening of infants at risk for significant hearing loss is a clinically efficient and cost effective approach for early detection of significant hearing loss."**

Combined OAE and AABR Screening Approach: Recent Findings

- **Xu & LI (2005). Performance of two hearing screening protocols in the NICU. *B-ENT, 1*, 11-15 [Shanghai China]**
  - **N = 200 NICU infants**
  - **Initial DPOAE failure rate = 14.5%**
  - **Combined DPOAE/AABR failure rate = 4.5%**
  - **At 3 months, 3% of infant had ABR confirmed hearing loss**
  - **None of the infants referred by DPOAE who passed AABR had actual hearing loss**

Combined OAE and AABR Screening Approach: Recent Findings

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journal homepage: www.elsevier.com/locate/ijporl

Outcomes with OAE and AABR screening in the first 48 h—Implications for newborn hearing screening in developing countries

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[b] Ear Sciences Centre, School of Surgery, The University of Western Australia, Nedlands, WA, Australia
[c] Ear Science Institute Australia, Subiaco, WA, Australia
[d] Osborne College of Audiology, Salus University, Elkins Park, PA, USA

Combined OAE and AABR Screening Approach:

(Van Dyk, Swanepoel & Hall, 2015)

N = 150 babies (300 ears)

TOAEs
(GSI AudioScreener)

AABR
(Maico MB 11)

Combined OAE and AABR Screening Approach:

(Van Dyk, Swanepoel & Hall, 2015)

N = 150 babies (300 ears)

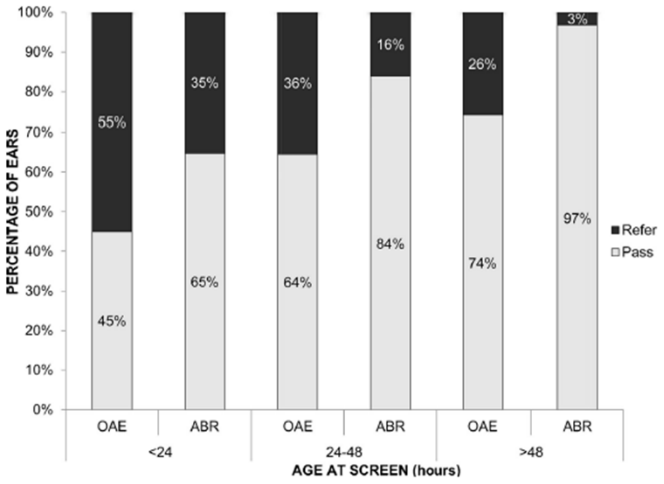

Fig. 3. Initial screening outcomes according to age at screen (TEOAE $n = 289$ ears; AABR $n = 290$ ears).

OAE and AABR Screening Techniques:

2007 Joint Committee on Infant Hearing Recommendations

- **Well baby nursery (WBN)**
  - **Screening with OAEs or AABR**
  - **Refer outcome for AABR**
    - ✓ **Schedule for diagnostic follow up assessment < 3 months**
  - **Refer outcome for OAEs?**
    - ✓ **Immediate follow up screening with AABR**
  - **Refer outcome for OAEs and AABR?**
    - ✓ **Schedule for diagnostic follow up assessment < 3 months**
- **Neonatal intensive care unit (NICU) or intensive care nursery (ICN)**
  - **Screening AABR (to detect auditory neuropathy)**
  - **Pass outcome for AABR?**
    - ✓ **Follow as indicated by risk factors for progressive/delayed onset hearing loss**
  - **Refer outcome for AABR?**
    - ✓ **Perform OAEs to identify possible auditory neuropathy**
    - ✓ **Schedule for diagnostic follow up assessment < 3 months**

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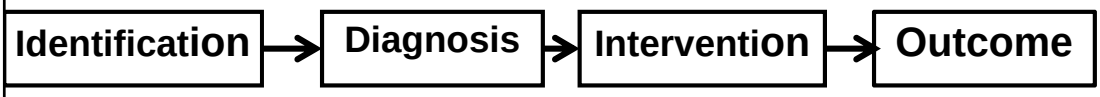

Identification	Diagnosis	Intervention	Outcome
• Screening • History • Parent-Referral • Professional referral	• Hearing loss • SNHL • CHL • Unilateral • ANSD • APD • Vestibular disorder	• Hearing aids • Aural Rehab • Counseling • Cochlear implant (s) • Vestibular rehab • Drugs • Surgery	• Effective communication • Efficient communication • Academic success • Financial independence • Quality of life

Thank You!
Questions?

Austin Hall screens Victoria Hall (July 1986)

Austin, Alessandra, Charlie & Ana Sofia Hall (October 2015)