Best Practices in Audiology Today: Principles, Procedures, Protocols & Populations

"Those who fall in love with practice without science are like a sailor who steers a ship without a rudder or compass, and who can never be certain whither he is going."

Leonardo Da Vinci (1452-1519)

Best Practices in Audiology Today *or* New Ideas About the Old Test Battery

- A trip down memory lane
  - Origins of audiology
  - Life in the late 1940s
- Thoughts about standards of care, or guidelines, for audiologic practice
- Good and bad news about clinical guidelines
- Current resources for practice guidelines in audiology
- Examples of some existing practice guidelines
  - children
  - Adults
- A critical review at current test procedures and batteries
- Ideas for new practice guidelines
- Conclusions and discussion

Gustav Theodore Fechner

(April 19, 1801 – November 18, 1887)

Inventor of Psychophysics

Hermann Ludwig Ferdinand von Helmholtz
(1821-1894)

Hearing Science Research Centers: Foundation of the Profession of Audiology (1930 – 1950)

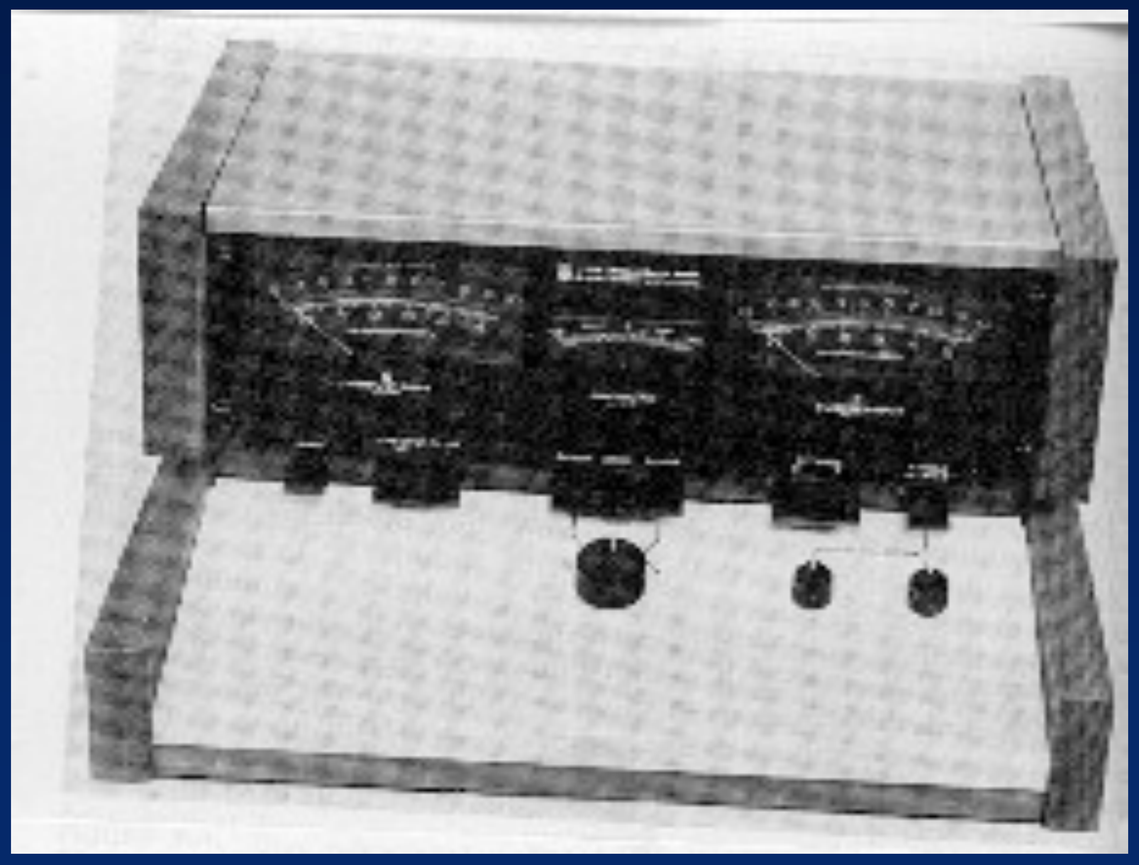
Georg von Bekesy
(1899 - 1972)

Experiments in Hearing
Georg von Bekesy
(1960)

PREFACE

"In my work at the Psycho-Acoustics Laboratory of Harvard University, I am especially indebted to Mr. Ralph Gerbrands and Mr. Rufus L. Grason for their assistance in the development of mechanical and electrical equipment."

GSI 1720 Immittance Meter: Back when you needed to understand immittance to measure it



An audiologists' simple pleasure … turning a well machined knob.

GSI 162
old speech
audiometer
(Serial # 402)

GSI E-800
old Bekesy
Audiometer

JWH 3
old audiologist

Robert Galambos:
Pioneer in ABR and Newborn Hearing Screening

NEWBORN HEARING SCREENING WITH ABR: Early Events

- **1969: Downs MP & Hemenway. Report on the hearing screening of 17,000 neonates.** *International Audiology 8.*
- **1971: Jewett DL & Williston JS. Auditory evoked far fields averaged from the scalp of humans.** *Brain 4*.
- **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*:

Ira Hirsh

Hallowell Davis
“Father of Auditory Evoked Responses”

TENNESSEE HEARING
AND
SPEECH FOUNDATION

HEARING

Its Psychology and Physiology

BY

STANLEY SMITH STEVENS, PH.D

Department of Psychology
Harvard University

AND

HALLOWELL DAVIS, M.D.

Director of Research
Central Institute for the Deaf
St. Louis, Mo.

no. 37

NEW YORK
JOHN WILEY & SONS, INC.
LONDON: CHAPMAN & HALL, LIMITED

1938

THE MEASUREMENT OF HEARING

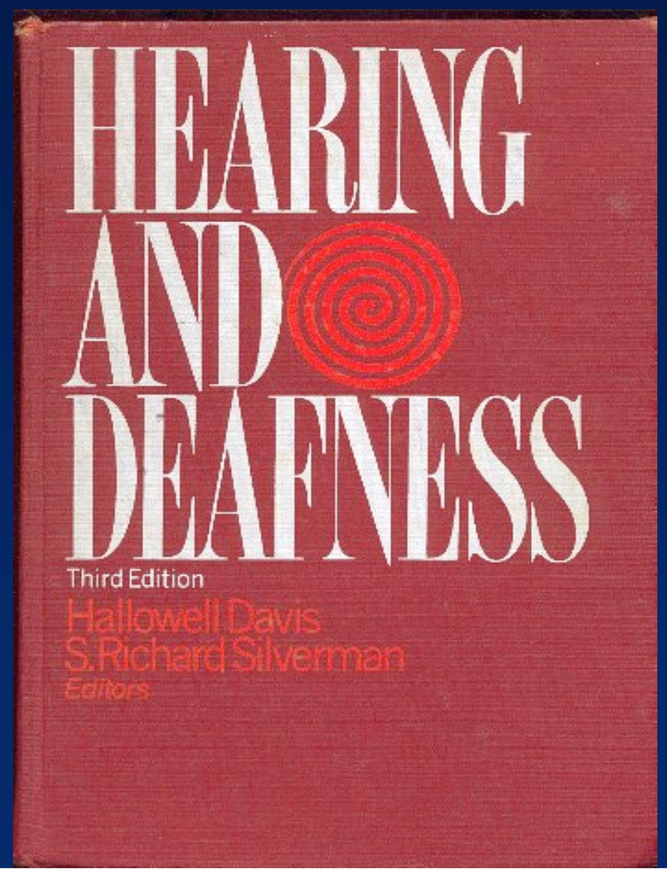
IRA J. HIRSH, *Central Institute for the Deaf and Washington University, St. Louis, Missouri; formerly Research Fellow, Psycho-Acoustic Laboratory, Harvard University*

McGRAW-HILL BOOK COMPANY, INC.
1952 NEW YORK TORONTO LONDON

4/65

LIBRARY
DILL WILKERSON HEARING & SPEECH CENTER

My Introduction to Audiology Textbook in 1971
(Instructor: Earl Harford, Ph.D., Northwestern U.)



Hearing Science Research Centers: Foundation of the Profession of Audiology (1930 – 1950)

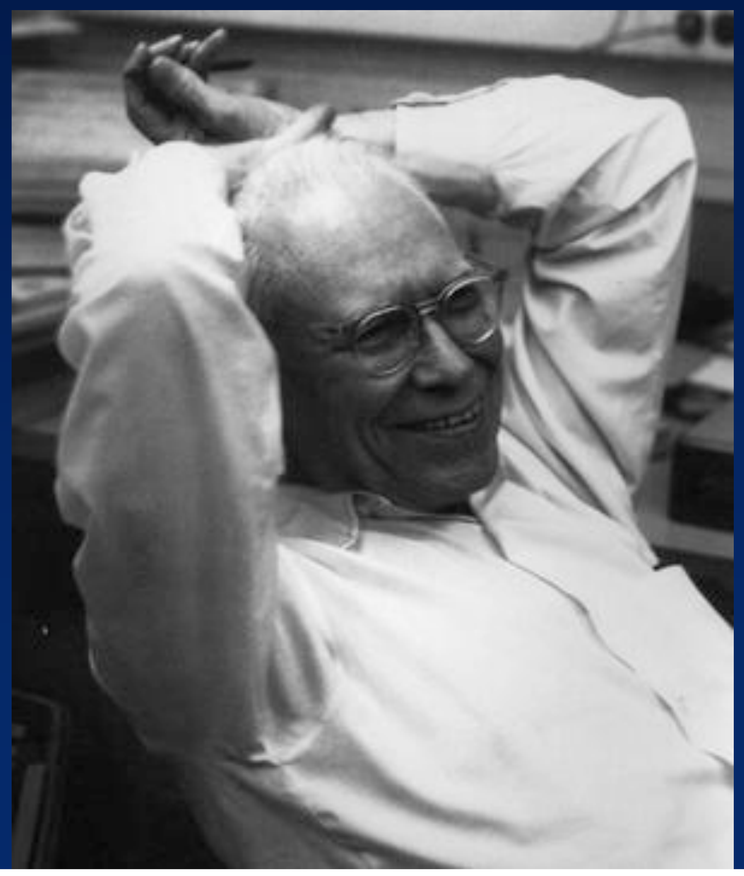
Harvey Fletcher
(1884-1981)

Foundation of the Profession of Audiology: Giants with Big Shoulders

- Psychoacoustic Laboratory at Harvard University (Cambridge/Boston)
  - Stanley Smith "Smitty" Smith (1906-1973)
  - Ira Hirsh (still alive and well)
  - Hallowell Davis (1896-1992)
  - Georg von Bekesy (1899-1972)
  - Robert Galambos (still alive and well)
  - CV Hudgins
  - *Douglas Ross*
- Bell Laboratory (Murray Hill, NJ)
  - Harvey Fletcher (1894-1981)

Ernest Glen Wever

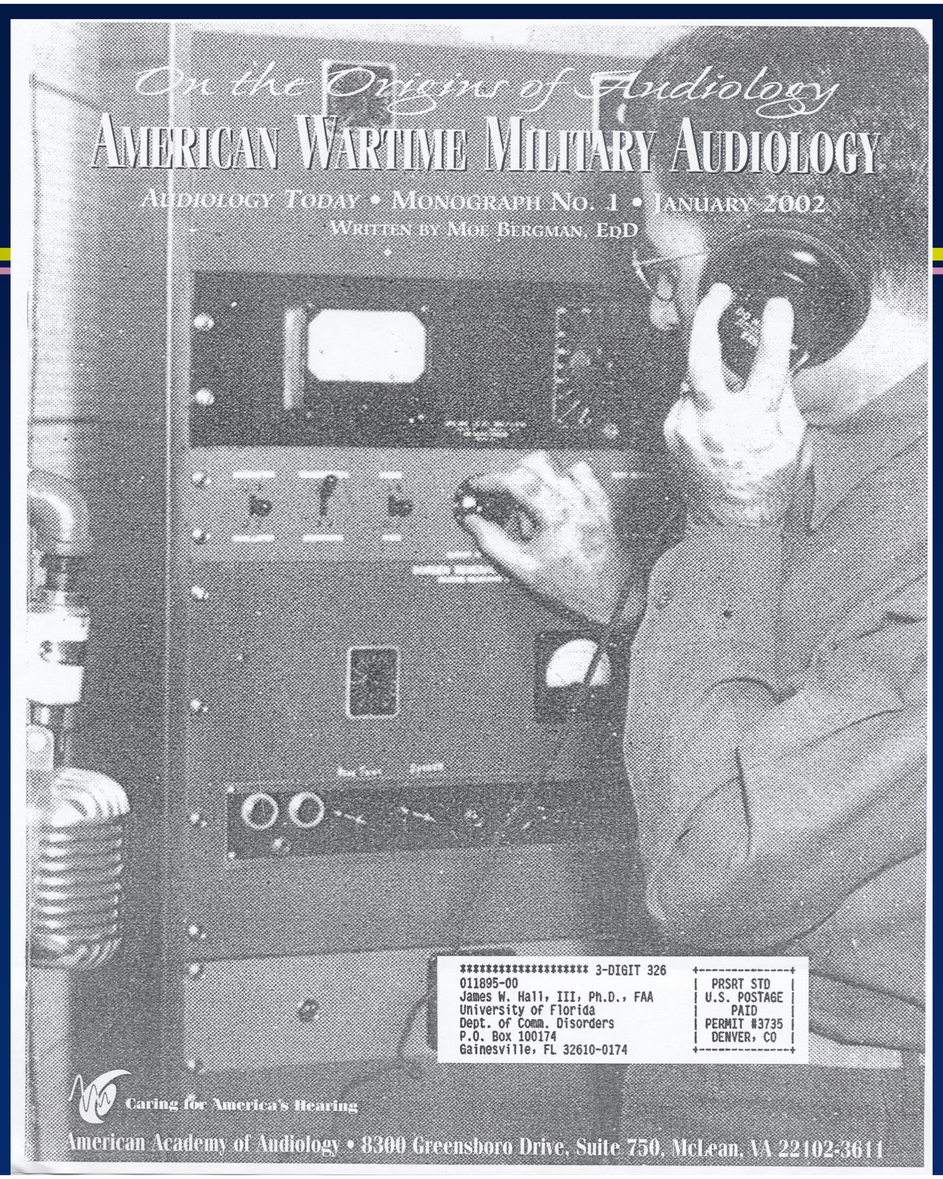
(October 16, 1902 — September 4, 1991)



Original Description of Electrocochleography (ECochG)

Wever EG and Bray CW. 1930. Action currents in the auditory nerve in response to acoustic stimulation. Proceedings of the National Acad of Science (USA) 16: 344-350.

Wever EG and Bray CW. 1930. Auditory nerve impulses. Science 71: 215.


On the Origins of Audiology
American Wartime Military Audiology
Audiology Today • Monograph No. 1 • January 2002
Written by Moe Bergman, EdD
********** 3-DIGIT 326
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DENVER, CO
Caring for America's Hearing
American Academy of Audiology • 8300 Greensboro Drive, Suite 750, McLean, VA 22102-3611

Foundation of the Profession of Audiology: Military Aural Rehabilitation during WW II

- Deshon Army General Hospital (Butler, PA)
  - Capt. Raymond Carhart *(Northwestern University)*
  - Pfc. Leo Doerffler *(Univ. of Pittsburgh)*
- Borden Army General Hospital (Chickasha, OK)
  - 2nd Lt. Moe Bergman *(clinical audiologist in NYC with Dr. Heller)*
  - Capt. Grant Fairbanks
  - T/4 Freeman McConnell *(Northwestern U. and Vanderbilt U.)*
- Other "Big Names" of the era
  - Frank Lassman *(University of Minnesota)*
  - Miriam Pauls
  - William Hardy *(Johns Hopkins Medical Center)*
  - Shirley Stein
  - Louie DiCarlo
- Has anyone seen the recent movie "Wind Talkers"?

Leo Doerfler (1919 – 2004)
University of Pittsburgh

Leo Doerfler, audiology pioneer, dies

By David H. Kirkwood

Leo G. Doerfler, who helped launch audiology in the 1940s and then spent much of his career battling to keep his profession on course, died on July 7 in Oyster Bay Cove, NY, at the age of 85.

In his work during World War II with Raymond Carhart, the "father of audiology," Doerfler was one of the field's true pioneers. At Carhart's urging, he went to Northwestern University, where he became the second person to earn a PhD in audiology. In the 1970s, the former president of the American Speech-Language-Hearing Association (ASHA) bucked the establishment that he had led and began dispensing hearing aids for profit. He was also the founding president of the Academy of Dispensing Audiologists (ADA) and an early leader in the movement to make the AuD the professional doctorate in audiology.

Doerfler

ALWAYS A NON-CONFORMIST

From an early age, Leo Doerfler shunned the conventional path. Born June 25, 1919, in New York City to Anna (Steiner) and Gustav Doerfler, he earned degrees in English literature from New York University and Columbia, but then accepted a scholarship at the Central Institute for the Deaf (CID) and earned his master's degree in deaf education. At CID, he also met Alice Turechek, a young teacher of the deaf, who was to be his wife for nearly 57 years until her death in 2000.

In 1941, Doerfler took a job at the Iowa State School for the Deaf, then enlisted in the army in 1942. He showed an early willingness to challenge authority when we went AWOL to be with his wife while she was undergoing an appendectomy. Fortunately, his friends covered for him and his absence went unpunished.

In 1943, the day before he was to be shipped to Germany, Doerfler was instead assigned to be an acoustic officer at Deshon General Hospital in Butler, PA. There, he and three others treated soldiers with hearing losses. They were soon joined by Carhart, and the work they did during the war helped lay the foundation for audiology.

FOUNDED PITTSBURGH PROGRAM

to accredit audiology programs.

Despite his prominence in ASHA, Doerfler was frequently at odds with the establishment. He began a dispensing program at the University of Pittsburgh, despite, as he later told *The Hearing Journal*, being "threatened with excommunication or disembowelment" by ASHA.

ENTERED PRIVATE PRACTICE

In 1976, at age 57, Dr. Doerfler left academia to start a private dispensing audiology practice in Greensburg, PA, outside of Pittsburgh. In 1977, he and seven like-minded audiologists met in Colorado Springs, CO, where they launched the Academy of Dispensing Audiologists. Doerfler was elected president and presided over the first ADA convention in 1978.

Writing on ADA's web site a few years ago, Doerfler recalled that tumultuous time: "My academic friends did not support the concept of the ADA and let me know at ASHA conventions and through the mail. Most are now dispensing, although none ever admitted being wrong."

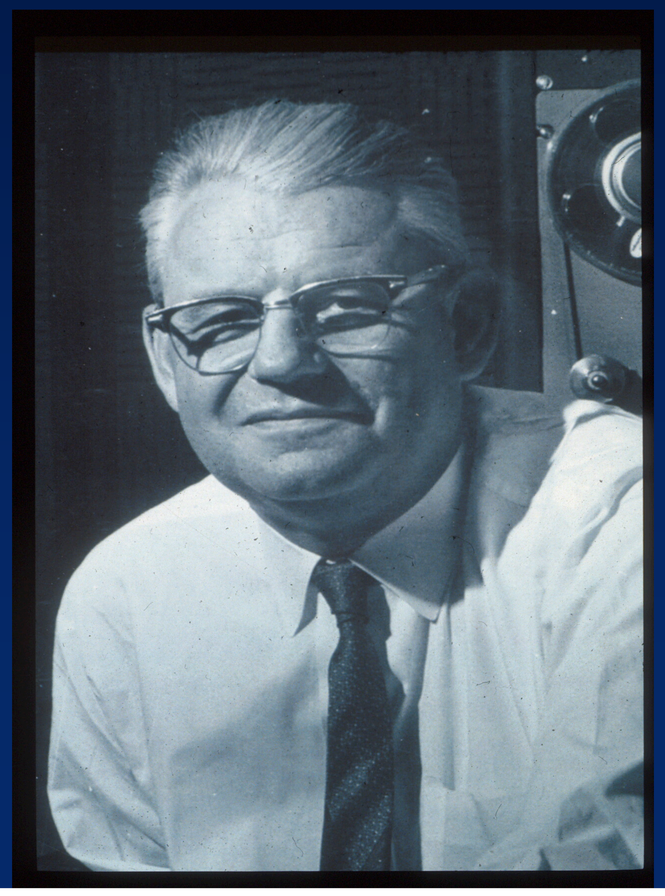
A 1978 Supreme Court ruling in an indirectly related case forced ASHA to lift its ban on dispensing, and Doerfler resumed being active there. In the 1980s, he fought to have ASHA recognize audiology as a separate profession from speech pathology and later urged ASHA to endorse the AuD. He lost those battles at the time, but lived to see the association reverse its position on both issues.

Doerfler helped establish the Audiology Co-Op, one of the earliest buying groups, and served as its first president and later chairman of its board. In 1988, he was one of the 31 audiologists who joined James Jerger, PhD, in founding the American Academy of Audiology.

Doerfler was one of the first to embrace the AuD. In 1988, he and 24 other audiologists attended the ADA-sponsored Conference on Professional Education in Chicago, where the campaign for the professional doctorate began. Afterwards, he helped create a model curriculum for the AuD and served on the board of the Audiology Foundation of America.

Doerfler received many honors and awards, including AAA's first Career Award in Hearing in 1994, and ADA's 1991 Wernick Award in recognition of outstanding edu-

Raymond Carhart, Ph.D.
“Father of Audiology”



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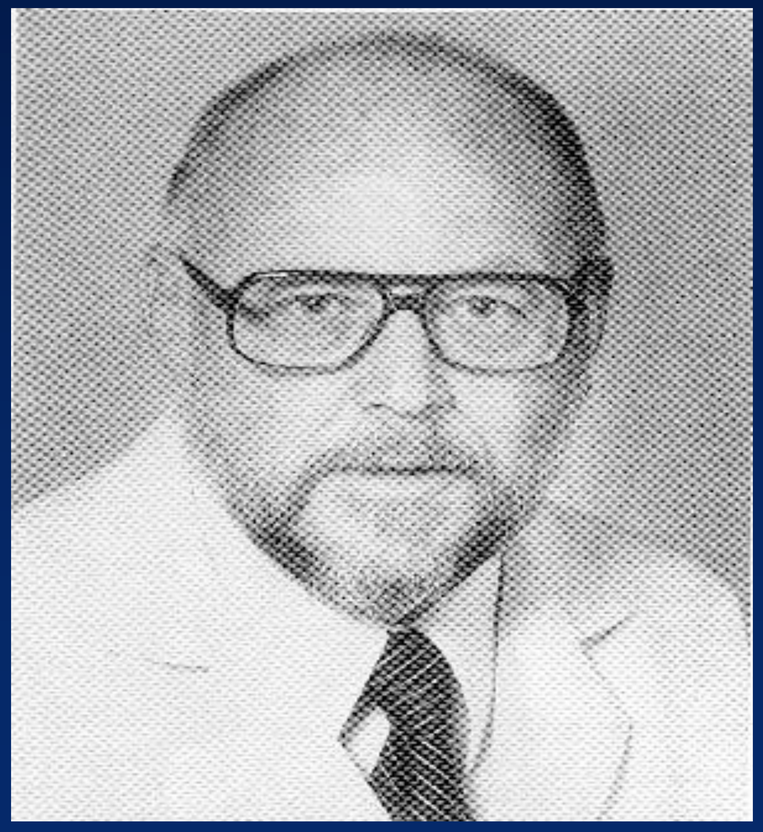
Expansion of Audiology after WW II
(1948 - 1975)

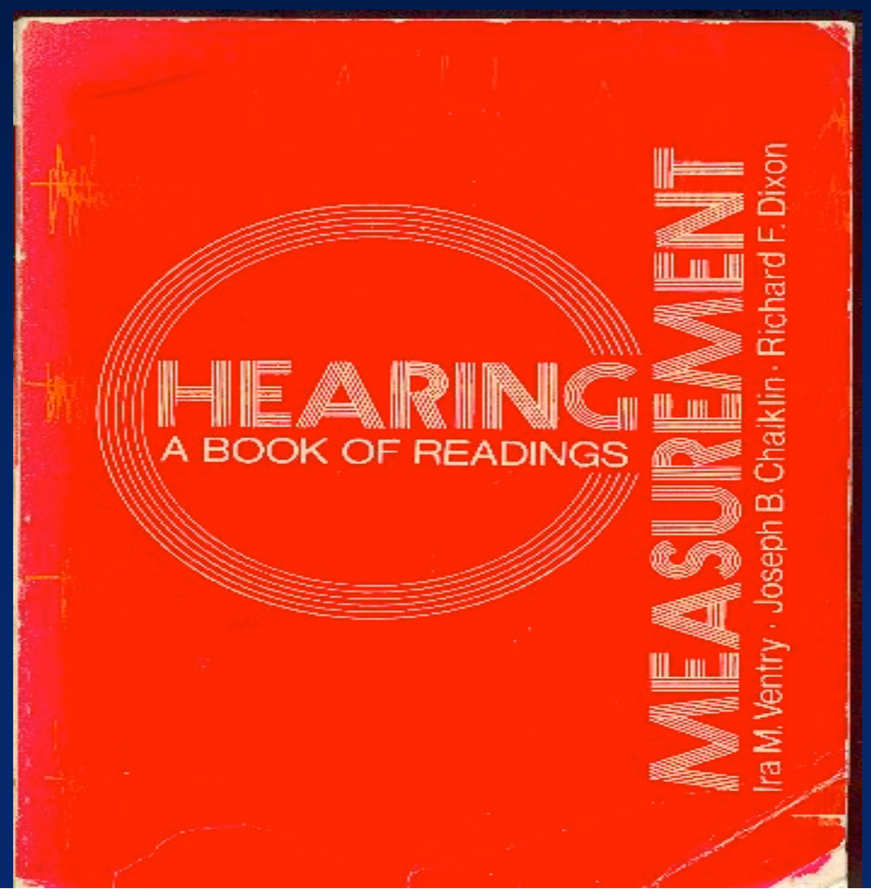
James Jerger
“Father of Diagnostic Audiology”



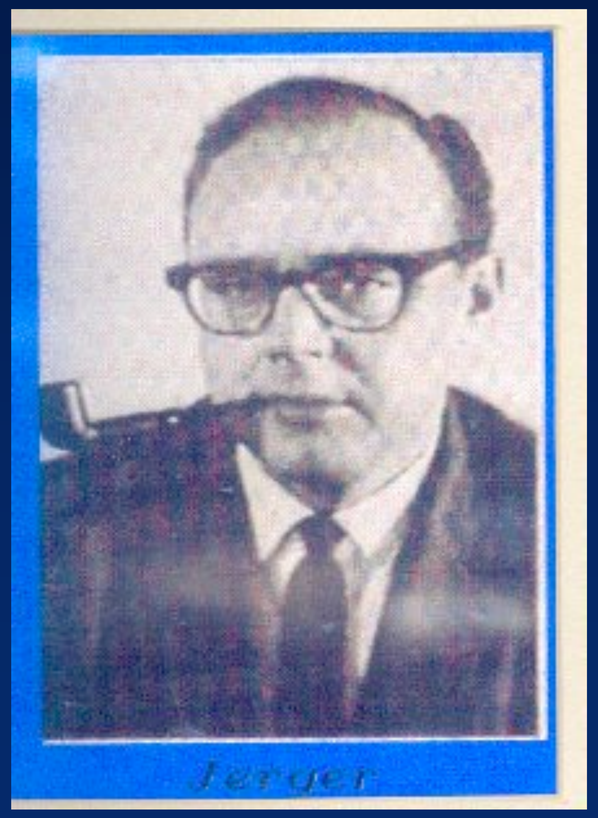
Northwestern University (1971- 1973): Beginning of my conversion from speech pathology to audiology

- Raymond Carhart
- Earl Harford
- Noel Matkin
- Tom Tillman
- Wayne Olsen
- Helmer Myklebust

One of My Favorite School Books in 1971
Course: **Current Trends in Audiology**
NU Instructors: **Noel Matkin & Tom Tillman**



The Early James Francis Jerger



Belief in the Gospel of Audiology According to St. James: The Conversion is Complete

Audiology Test Battery: 60 years Ago

- Test battery at the beginning of our profession, in order of test administration
  - Air-conduction pure tone audiometry
  - Bone-conduction pure tone audiometry
  - Speech reception thresholds
  - Word recognition (PB word lists)
  - Uncomfortable loudness level (UCL), i.e., loudness discomfort level (LDL)

Source: Wiener F & Miller G. Hearing aids. In Combat Instruments II. Washington, D.C. NDRC Report 117, 216-232, 1946

Baby Boomer HeadQuarters

Terrific gifts for boomers - Click the pic for more information:

Boomer Time Capsule Report

Click here

The BBHQ JukeBox 200 Oldies 24/7

Click here

The year was 1946 …

- Movies
  - It's a Wonderful Life
  - My Darling Clementine
  - The Postman Always Rings Twice
  - The Yearling *(Marjorie K. Rawling)*
- Television
  - December, 1947. The children's television series "Howdy Doody" premieres on NBC.
- Literature
  - The Nobel Prize goes to Hermann Hesse

Events in 1946 …

- Weather
  - On April 1, 1946, at 12:29 GMT, an earthquake occurred in the Aleutian Islands of Alaska. A Pacific-wide tsunami was triggered by the earthquake, which had a surface-wave magnitude of 7.8, an epicenter of 52.8° N, 163.5° W, and a focal depth of 25 km. Before the tsunami dissipated it took the lives of more than 165 people and cause over $26 million (1946 dollars) in damage.

- International Affairs
  - 1946. The International Tribunal at Nuremberg convicts 22 Nazi leaders of war crimes. Goering commits suicide before his scheduled execution.

The year was 1946 …

- Sports (American and National League)
  - Boston Red Sox second baseman Johnny Pesky became the first American League player to single-handedly score six runs in a game during a 14-10 triumph over the Chicago White Sox on May 8th for their thirteenth straight victory. Boston extended its streak to fifteen games before losing to their rivals, the New York Yankees, on May 11th.
  - On March 17th, the Brooklyn Dodgers played an exhibition game in Daytona Beach against their own Minor League farm team, the Montreal Royals. With Jackie Robinson in the line-up, it marked the first appearance of an integrated baseball team during the 20th century. As a fitting tribute, the field was later renamed Jackie Robinson Ballpark.

The great Ted Williams in 1946

Baseball Standings in 1946

- 1946 American League
  - Boston Red Sox, 104-50*, .675, 0
  - Detroit Tigers, 92-62, .597, 12.0
  - New York Yankees, 87-67, .565, 17.0
  - Washington Senators, 76-78, .494, 28.0
  - Chicago White Sox, 74-80, .481, 30.0
  - Cleveland Indians, 68-86, .442, 36.0
  - St.Louis Browns, 66-88, .429, 38.0
  - Philadelphia Athletics, 49-105, .318, 55.0

** 2004 season: 98-64*

1946 …Transportation in Style

Best Practices in Audiology Today:
The Old and the New

The Audiology Test Battery Today: How far have we come after 60 years of clinical research and experience?

Procedure	% performing procedure
Pure tone audiometry: air conduction	100%
Pure tone audiometry: bone conduction	100%
Word recognition	95%
Speech reception threshold	91%
UCL (LDL) for speech	83%
Tympanometry	45%
UCL (LDL) for tones	45%
Acoustic reflexes	20%
Otoacoustic emissions (OAEs)	4%

Source: The Hearing Journal, December, 2002

Best Practices in Audiology Today *or*
New Ideas About the Old Test Battery

- A trip down memory lane … life in 1946
- Terminology for discussing best practices in audiology
- Good and bad news about clinical guidelines
- Current resources for practice guidelines in audiology
- A critical review at current test procedures and batteries
- Examples of existing practice guidelines
  - children
  - adults
- An attempt to outline some new practice guidelines
- Conclusions and discussion

Best Practices in Audiology Today *or* New Ideas About the Old Test Battery

- Terms and concepts related to best practices
  - Standard of care
  - Clinical guidelines versus standards
  - Evidence based practice
  - Clinical pathways

Definitions of "Standard of Care"

- Consistent with local, regional or national clinical practice
- Federal guidelines for clinical practice and services, e.g., Joint Committee on Accreditation of Hospital Organizations (JCAHO)
- Guidelines or recommendations on clinical practice approved by national multi-disciplinary professional committees or panels, e.g., Joint Committee on Infant Hearing
- Guidelines or recommendations on clinical practice approved by national professional organizations, e.g., AAA or ASHA

Best Practices in Audiology Today *or*
New Ideas About the Old Test Battery

- A trip down memory lane … life in 1946
- Thoughts about standards of care, or guidelines, for audiologic practice
- Good and bad news about clinical guidelines
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“Clinical Pathways … What is everybody looking for?”

“Clinical pathways are pre-conceived patient care algorithms, or paths, that are intended to reduce variability and cost, increase efficiency, and ultimately improve patient care.

Whether or not such efforts prove to be effective in achieving such goals, many institutions are proceeding to develop such pathways.

While many policies and procedures must of necessity be constructed locally, there is likely enough common ground across institutions such that sharing pathways may be of great benefit. In other words, why should each center be forced to "reinvent the wheel?"

Standard of Care in Clinical Audiology Today: New Ideas About the Old Test Battery

- The good news … advantages of clinical guidelines
  - The main benefit is to improve quality of patient care.
  - Improve consistency in care, i.e., which procedures are administered with patients presenting with the same clinical problem.
  - Help patients to know what they should expect in healthcare, i.e., patients are empowered.
  - Guidelines, especially with the power of the internet, patients may educate health care providers on what care should be provided.
  - Clinical guidelines can influence public policy, and may influence reimbursement trends.
  - Reassure health care providers who are uncertain about the appropriateness of their diagnostisor treatment for a patient.
  - Reinforce evidenced-based clinical practice.
  - May reduce inefficient, costly, and even dangerous practices.

Standard of Care in Clinical Audiology Today: New Ideas About the Old Test Battery

- The bad news … disadvantages of clinical guidelines
  - Legal considerations of clinical guidelines
  - How quickly do clinical guidelines become outdated?
  - Clinical guidelines must be updated or clinical practice is out of date.
  - Conflicts between national "consensus" guidelines and community practice
  - Are guidelines "politics disguised as science"?
  - Guidelines can be time consuming and inefficient.
  - Guidelines can oversimplify complex health care decisions.
  - There is scant evidence that clinical guidelines actually do improve quality of patient care, and patient outcome
  - Is there a danger in relying on expert versus clinical judgment?
  - *And ….*

Standard of Care in Clinical Audiology Today: New Ideas About the Old Test Battery

- More bad news … disadvantages of clinical guidelines
  - Flawed guidelines may be developed and used inappropriately to gain reimbursement for services, or to limit reimbursement for clinical services.
  - Coverage may be dropped for services not delineated in guidelines.
  - Professions engage in "turf wars" to control guidelines.
  - Evidence is often lacking for guidelines. Very little clinical practice is adequately supported by good evidence (remember grades of evidence).
  - Guidelines are not a "magic bullet" for inferior health care.
  - Inflexible guidelines do not permit the clinician to take into account all factors in the patient's history and personal circumstances. Individualized patient care suffers.
  - The group developing the guidelines may be wrong.
  - *Guidelines may be wrong for an individual patient.*

Best Practices in Audiology Today *or*
New Ideas About the Old Test Battery

- A trip down memory lane … life in 1946
- Thoughts about standards of care, or guidelines, for audiologic practice
- Good and bad news about clinical guidelines
- Current resources for practice guidelines in audiology
- "Remember, time is $"
- Examples of existing practice guidelines
  - children
  - adults
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- Conclusions and discussion

Best Practices in Audiology Today: General Sources of Information on Practice Guidelines

- American Academy of Audiology (AAA)
- American Speech Language Hearing Association (ASHA)
- American Academy of Pediatrics
- American Academy of Otolaryngology Head & Neck Surgery
- V.A. Audiology Working Group
- National multi-disciplinary groups, e.g., Joint Committee on Infant Hearing
- Other?

Best Practices in Audiology Today: Specific Sources for Practice Guidelines

- Guidelines for different clinical practices, e.g.,
  - diagnostic audiometry in adults
  - pediatric diagnostic audiology
  - hearing aids and amplification
  - auditory processing disorders (APD) assessment and management
  - tinnitus assessment and management
- Selected sources of guidelines
  - V.A. guidelines in *Audiology Today*
  - Guidelines for otoacoustic emissions (OAEs). *AAA (in progress)*
  - Guidelines for auditory processing disorders. *AAA (in progress)*
  - Joint Committee on Infant Hearing 2000 Statement *(2005 out soon)*
  - Audiologic assessment of children birth to 5 years. *ASHA 2004*.
  - Consensus conference on APD. *JAAA 2002.*
  - Tinnitus guidelines *(www.audiology.org)*

Joint Committee on Clinical Practice (*Audiology Today*, www.audiology.org)

- Representation
  - American Academy of Audiology (AAA)
  - American Speech-Language-Hearing Association (ASHA)
  - Department of Veterans Affairs (VA)
- Practice guidelines and statements (N = 5)
  - Overview of audiologic services
  - Comprehensive audiologic assessment (adult)
  - Comprehensive audiologic assessment (pediatric)
  - Hearing aid selection and fitting
  - Cochlear implant assessment, programming, and audiologic rehabilitation (adult)

Best Practices in Audiology Today: Joint Committee on Clinical Practice

"The overall goal of the Joint Committee on audiology practice was to maximize the value of health care delivered to patients and clients. National consensus was sought on ideal practices, on maximizing quality through achieving desired outcomes, on customer satisfaction, and on efficient and appropriate use of procedures and resources."

Joint Audiology Committee:
11 Categories of Definitions in Practice Guidelines

- Personnel
- Referrals
- Procedures (CPT codes)
- Populations
- Clinical indicators
- Objectives
- Expected outcomes
- Clinical process
- Equipment and test environment
- Safety and health precautions
- References

Joint Audiology Committee: Components of Audiologic Assessment

- History
- Appropriate physical examination (e.g., otoscopy)
- Cerumen management
- Air conduction pure tone thresholds (w/ appropriate masking
- Bone conduction pure tone thresholds (w/ appropriate masking)
- Speech thresholds (w/ appropriate masking)
- Speech recognition measures (w/ appropriate masking)
- Acoustic immittance
  - tympanometry
  - acoustic reflexes
  - acoustic reflex decay
- Otoacoustic emissions
- High frequency audiometry
- Stenger (pure tone and speech)
- Rehabilitation needs assessment
- Communication inventory

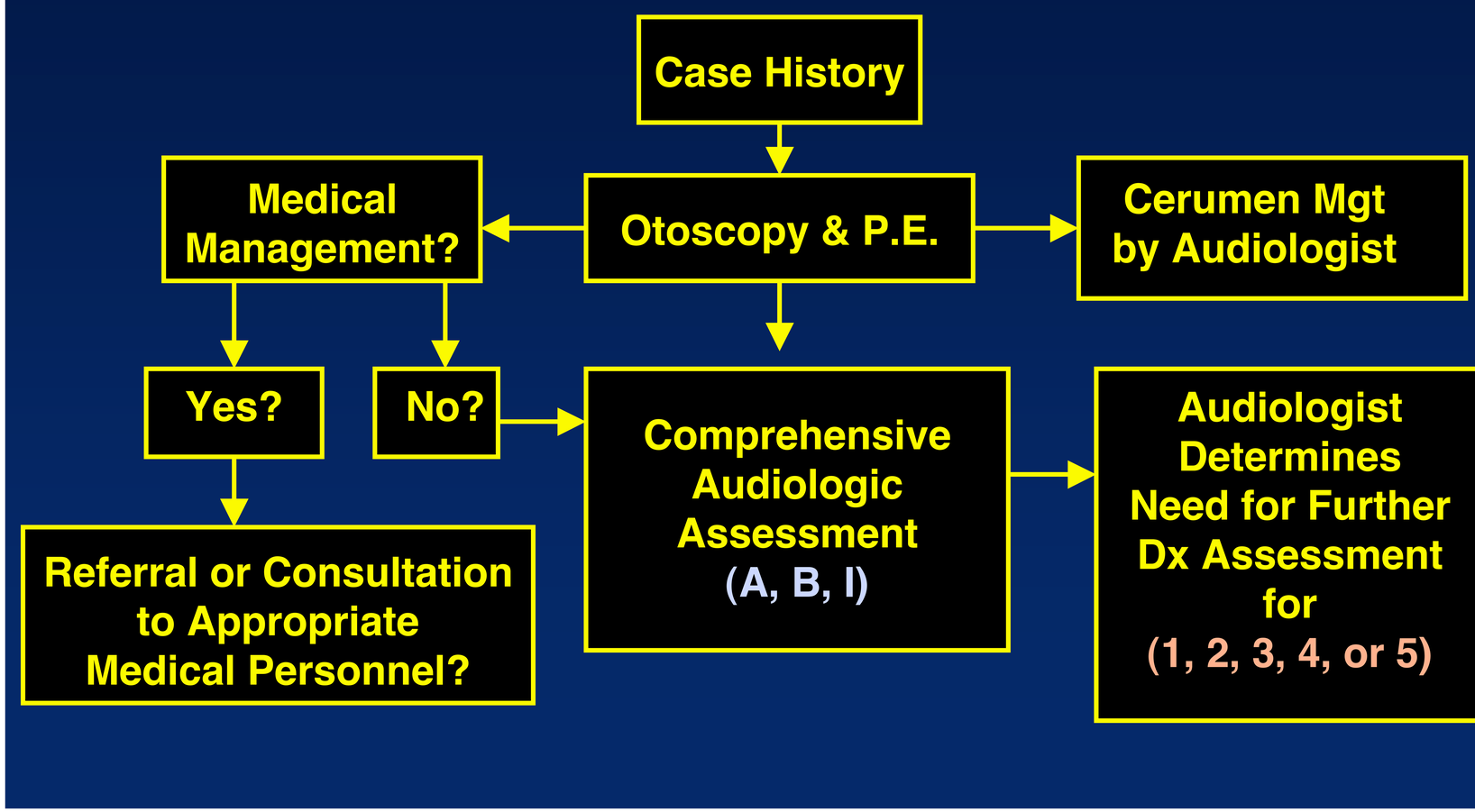
Joint Audiology Committee: Further diagnostic assessment options based on need

- Non-organic?
  - Non-organic assessment
- VIIIth nerve/peripheral brainstem pathology?
  - Electrophysiologic assessment
- CNS/APD disorder?
  - APD assessment
- Balance disorder?
  - Balance assessment
- Tinnitus problems?
  - Tinnitus assessment

Strength of Evidence used by Joint Audiology Committee for Practice Algorithms

- **Grade I:** Evidence is strong and usually obtained from randomized controlled trials or well-designed clinical studies.
- **Grade II:** Evidence is from clinical studies that were based on retrospective data analysis, clinical trials that were not randomized and/or carefully-controlled, or from panel consensus based on existing guidelines and practice patterns.
- **Grade III:** Evidence is secondary in that it is based on current or long-standing practice without substantial supporting basic or clinical data.

Joint Audiology Committee Algorithm on Comprehensive Audiologic Assessment (age 5 through adult)



Joint Audiology Committee: Audiologic Clinical Process

- Procedures in category "A" always include
  - air conduction pure tone thresholds
  - speech reception thresholds
  - word recognition
- Procedures in category "B" always include
  - bone conduction pure tone thresholds
- Procedures in category "I" always include
  - acoustic immittance measures
    - ✓ tympanogram
    - ✓ acoustic reflex

Best Practices in Audiology Today *or*
New Ideas About the Old Test Battery

- A trip down memory lane Thoughts about standards of care, or guidelines, for audiologic practice
- Good and bad news about clinical guidelines
- Current resources for practice guidelines in audiology
- Other examples of existing practice guidelines
  - children
  - adults
- A critical review at current test procedures and batteries
- Conclusions and discussion

Best Practices in Audiology Today *or* New Ideas About the Old Test Battery

- Examples of other existing practice guidelines
  - Medical referral criteria
  - Diagnostic audiologic assessment of infants
  - APD: screening and assessment
  - Tinnitus assessment and management

Medical Referral Guidelines:
AAOHNS 7 Signs of Serious Ear Disease

- Ear pain or fullness
- Discharge or bleeding from the ear
- Sudden or progressive hearing loss
- Unequal hearing between ears or tinnitus
- Hearing loss after an injury, loud sound, or air travel
- Slow or abnormal speech development in children
- Balance disturbance or dizziness

"When in doubt … refer out?"

Year 2000 JCIH Position Statement: Principles and Guidelines for Early Hearing Detection and Intervention Programs

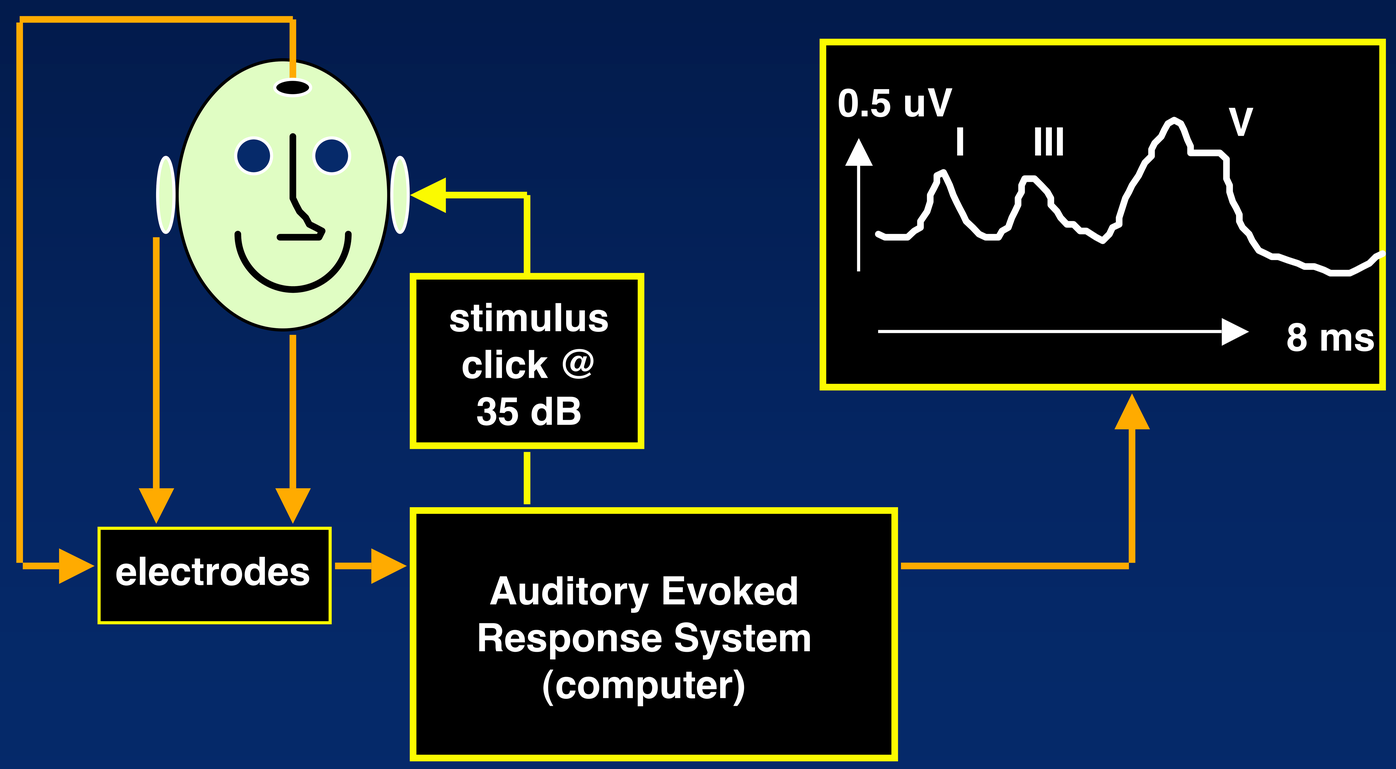
- JCIH = Joint Committee on Infant Hearing
- Published in:
  - *Audiology Today (Special Issue):* August 2000, pp. 6-27
  - *American Journal of Audiology 9*: 9-29, 2000.
  - www.audiology.org
- Member organizations:
  - American Academy of Audiology & ASHA
  - American Academy of Otolaryngology-Head & Neck Surgery
  - American Academy of Pediatrics
  - Council on Education of the Deaf
  - Directors of Speech and Hearing Programs in State and Welfare Agencies

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."

Robert Galambos:
ABR in Newborn Infants and Young Children
1974

Newborn Hearing Screening with Auditory brainstem response (ABR)

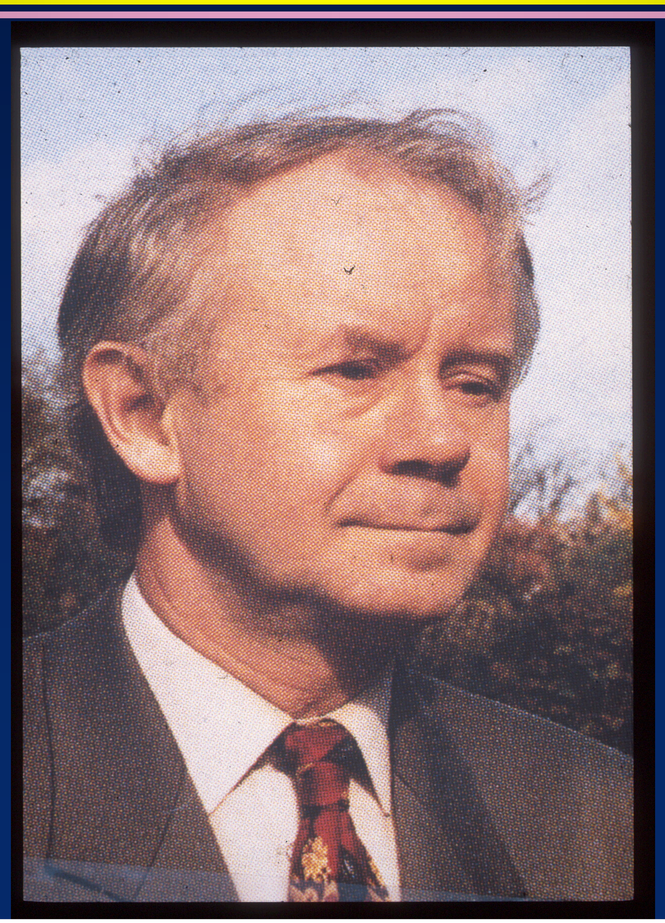


Beginning in 1974

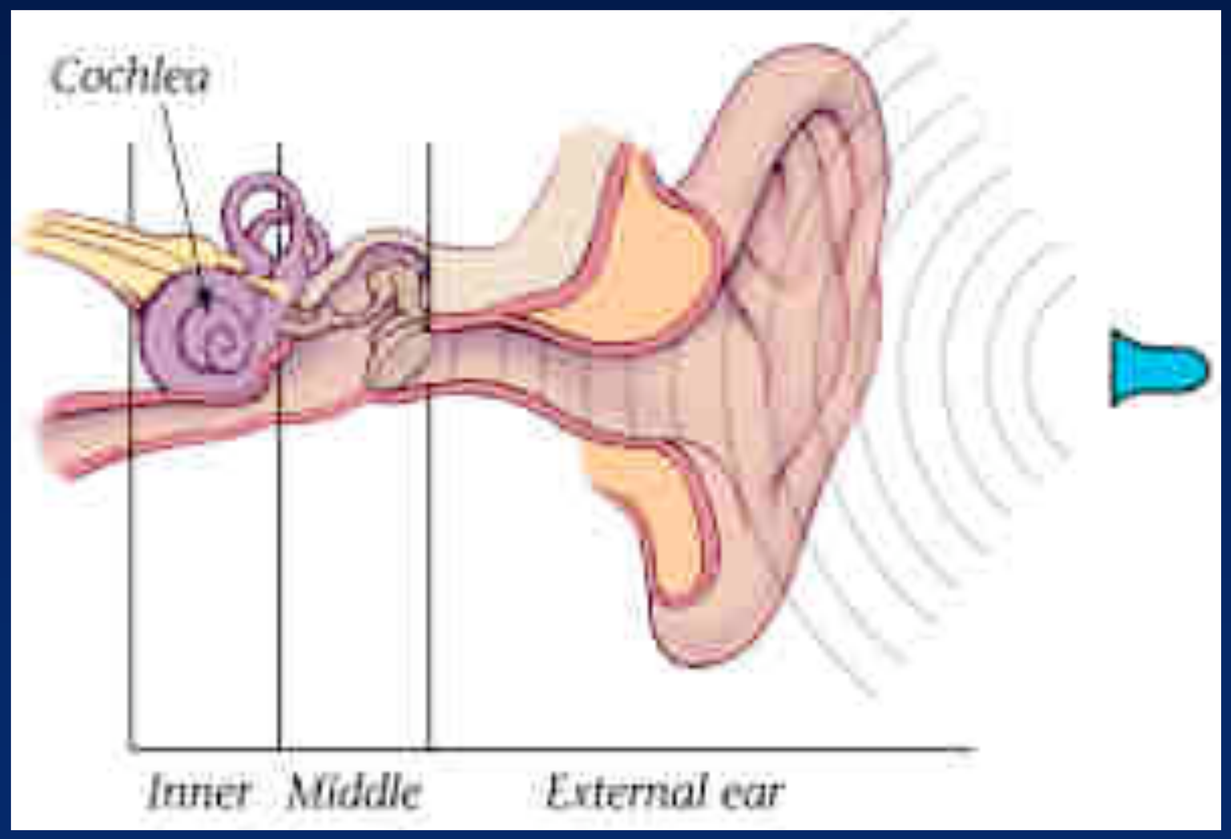
The Automated ABR (AABR) Technique for Newborn Hearing Screening

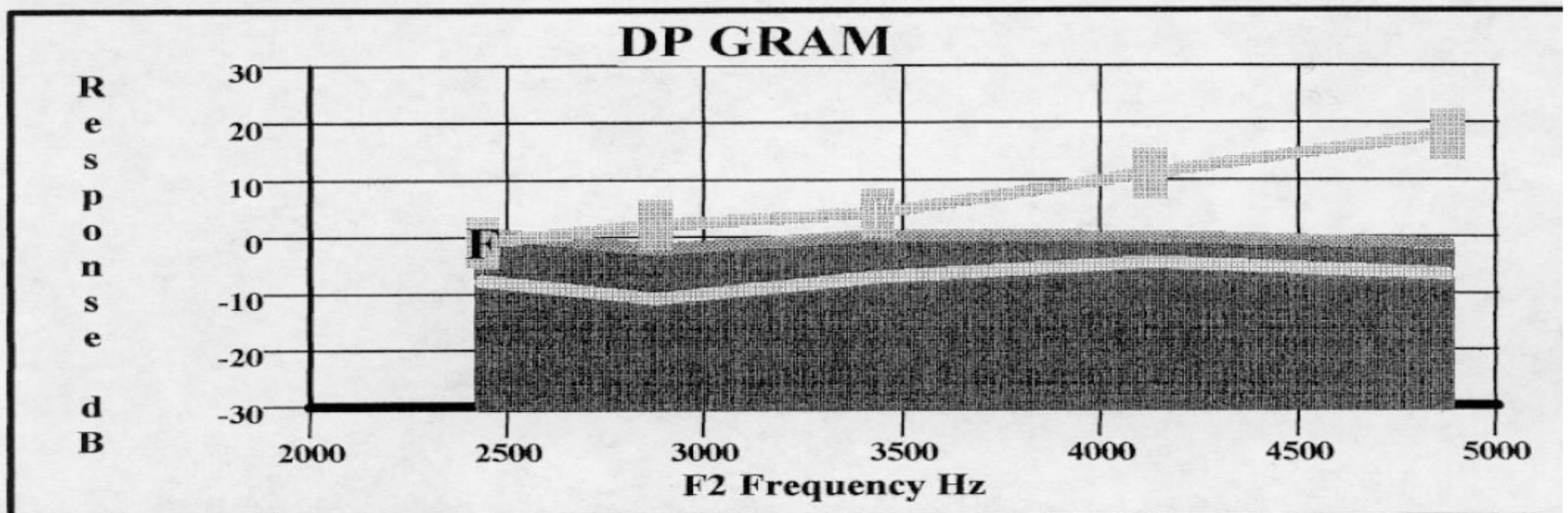
Automated ABR (AABR) in the late 1980s: The first step toward universal newborn hearing screening (UNHS)

David Kemp
“Discoverer of OAEs in 1978”



Otoacoustic Emissions (OAEs)





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

Newborn Hearing Screening with a Combined Automated OAE and ABR Technique

James W. Hall III, Ph.D.
University of Florida,
Gainesville, Florida, U.S.A.

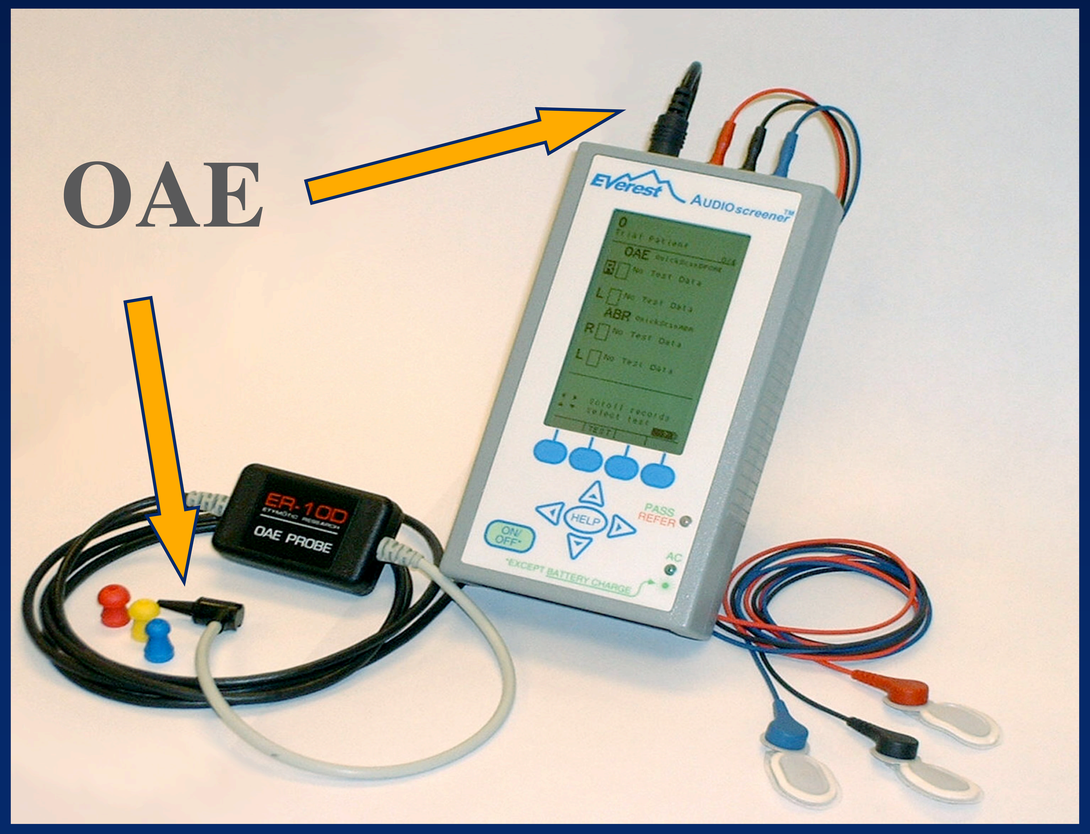
Steven D. Smith, Au.D.
Drs. Kitchens, Chapman & Anderson,
Montgomery, Alabama, U.S.A.

Gerald Popelka, Ph.D.
Everest Biomedical,
St. Louis, Missouri, U.S.A.

(Journal of American Academy of Audiology, August 2004)

OAE/ABR Data Collection

AUDIOscreener (Grason Stadler VIASYS)



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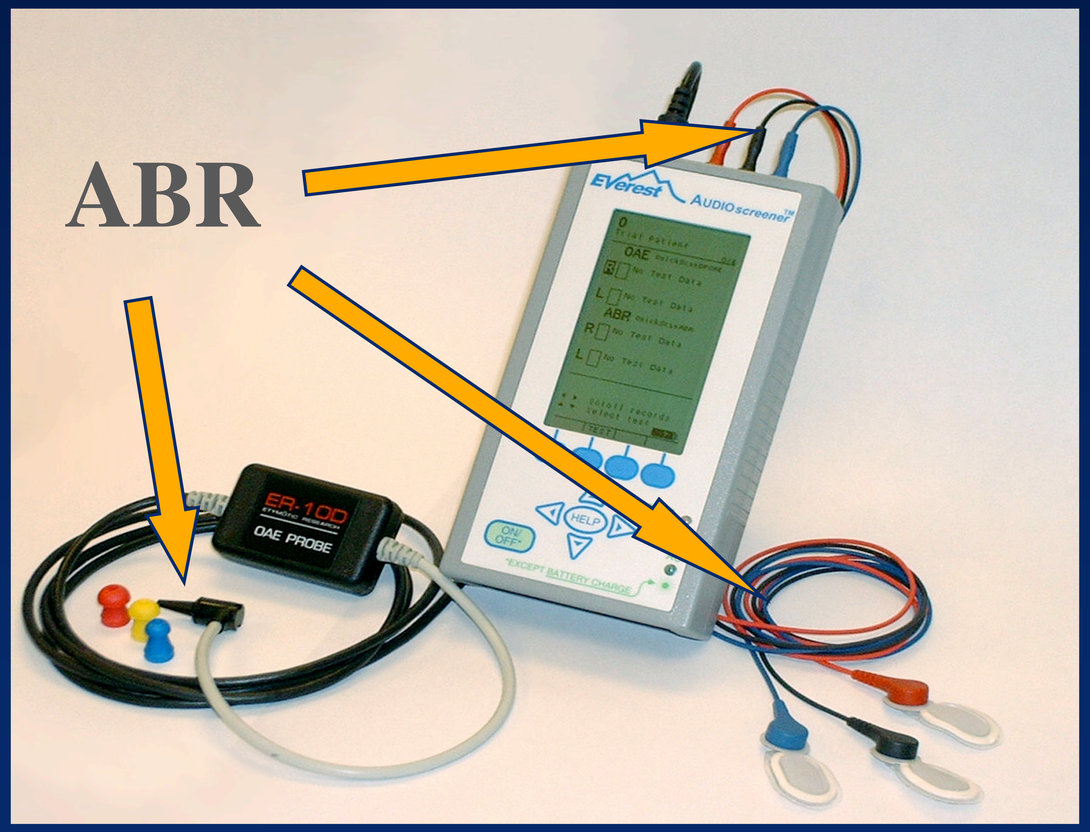


Combination OAE/ABR Screening: Differentiation of Peripheral Auditory Dysfunction

Type of dysfunction	OAE	ABR
External/middle ear *	abnormal	normal
Sensory (OHC)	abnormal	abnormal
Neural	normal	abnormal

** minor dysfunction*

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

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

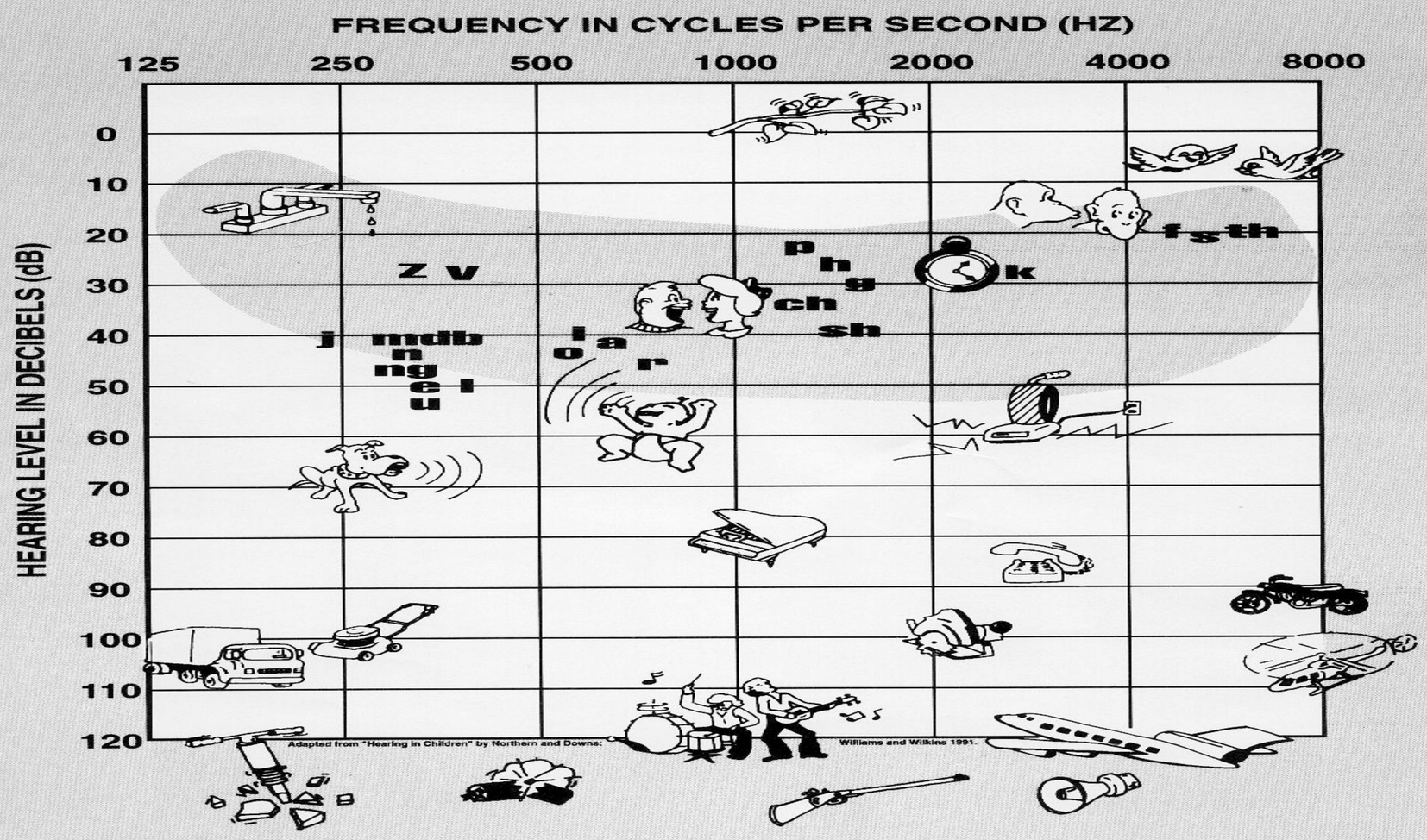
Sensitivity = 100.0%
Specificity = 99.7%

Refer Rate = 1.7%
Positive Predictive Value = 80.0%

Combined OAE/ABR Screening: Summary of Clinical Advantages

- In ear calibration of signal intensity for OAE *and* ABR
- Lower refer (< 2%) and false-positive rates (< 0. 2%)
- High sensitivity and specificity
- Fewer diagnostic follow-ups with lower overall cost for early identification of infant hearing loss
- Differentiation of auditory dysfunction at birth
  - conductive
  - sensory
  - neural (e.g., auditory neuropathy)
- Quicker and more appropriate management
- Earlier intervention hearing impairment

AUDIOGRAM OF FAMILIAR SOUNDS



Adapted from "Hearing in Children" by Northern and Downs; Williams and Wilkins 1991.

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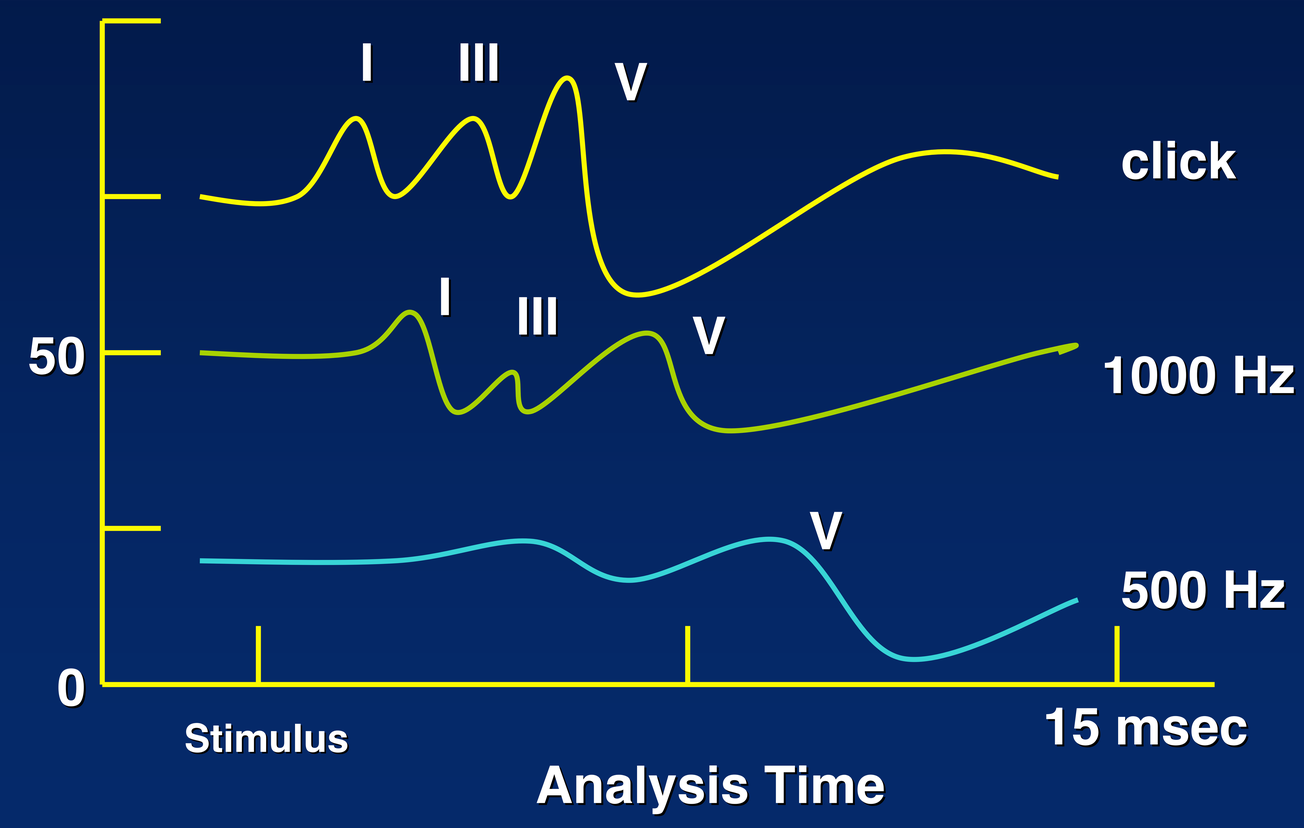
Click versus Tone Burst ABRs



Year 2000 JCIH Position Statement: Protocol for Confirmation of Hearing Loss In Infants and Toddlers (0 to 6 months)

- Child and family history
- Otoacoustic emissions
- ABR during initial evaluation to confirm
  - type of hearing loss
  - degree of hearing loss
  - configuration of hearing loss (ASSR now also)
- Acoustic immittance measures
  - tympanometry (high frequency probe tone)
  - acoustic reflexes
- Behavioral response audiometry *(if feasible)*
  - ✓ visual reinforcement audiometry *or*
  - ✓ conditioned play audiometry
  - ✓ speech detection and recognition
- Parental report of auditory & visual behaviors
- Screening of infant's communication milestones

Protocol for Confirmation of Hearing Loss In Infants and Toddlers (0 to 6 months): What about guidelines for each procedure?

- Procedures
  - Otoacoustic emissions (OAEs)
  - Auditory brainstem response (ABR)
  - Acoustic immittance measures
- Guidelines?
  - AAA Task Force statements
  - ASHA position statements
  - State guidelines, e.g., Florida

Guidelines are needed for ….

(For example, OAEs)

- Clinical indications for procedure
- Test parameters for different clinical applications, e.g.,
  - Stimulus intensity levels (f_1 and f_2)
  - Frequencies per octave
  - f_2 / f_1 ratio
- Analysis criteria, e.g.,
  - Reliability
  - Minimum OAE – noise floor difference for response
  - Maximum noise floor level
  - Normative data
  - Definition of criteria for normal OAE, present but abnormal OAE, and no response
- Appropriate statements about auditory function based on OAE findings

Guidelines are also needed for ABR applications

- Test parameters for estimation of auditory sensitivity with ABR, for example …

Frequency-Specific ABR Test Protocol: Stimulus Parameters

Parameter	Selection	Rationale
Transducer	ER-3A inserts	numerous infant advantages
Type	tone bursts	available on all systems
Frequencies	1, .5, 4, 2 K Hz	sequence varies clinically
Duration	2-0-2 cycles	abrupt frequencies 0 plateau < spectral splatter

Frequency-Specific ABR Test Protocol: Stimulus Parameters

Parameter	Selection	Rationale
Polarity	alternating	minimize stimulus artifact
Rate	27.1/sec	rapid data collection with adequate response integrity with longer analysis time
Intensity	dB nHL	RE: adult behavioral data, but variable iunknown ncreases in effective intensity for infants are likely

Frequency-Specific ABR Test Protocol: Acquisition Parameters

Parameter	Selection	Rationale
Artifact reject	on	minimize muscle artifact
Analysis time	20 ms	encompass delayed wave Vs and SN10 after wave V
Sweeps	100 to > 2000	whatever is needed for SNR for poor morphology ABRs
Reliability	2 or 3 runs (then add)	“if it doesn’t replicate, you must investigate” or “if it doesn’t repeat … your test is not complete”

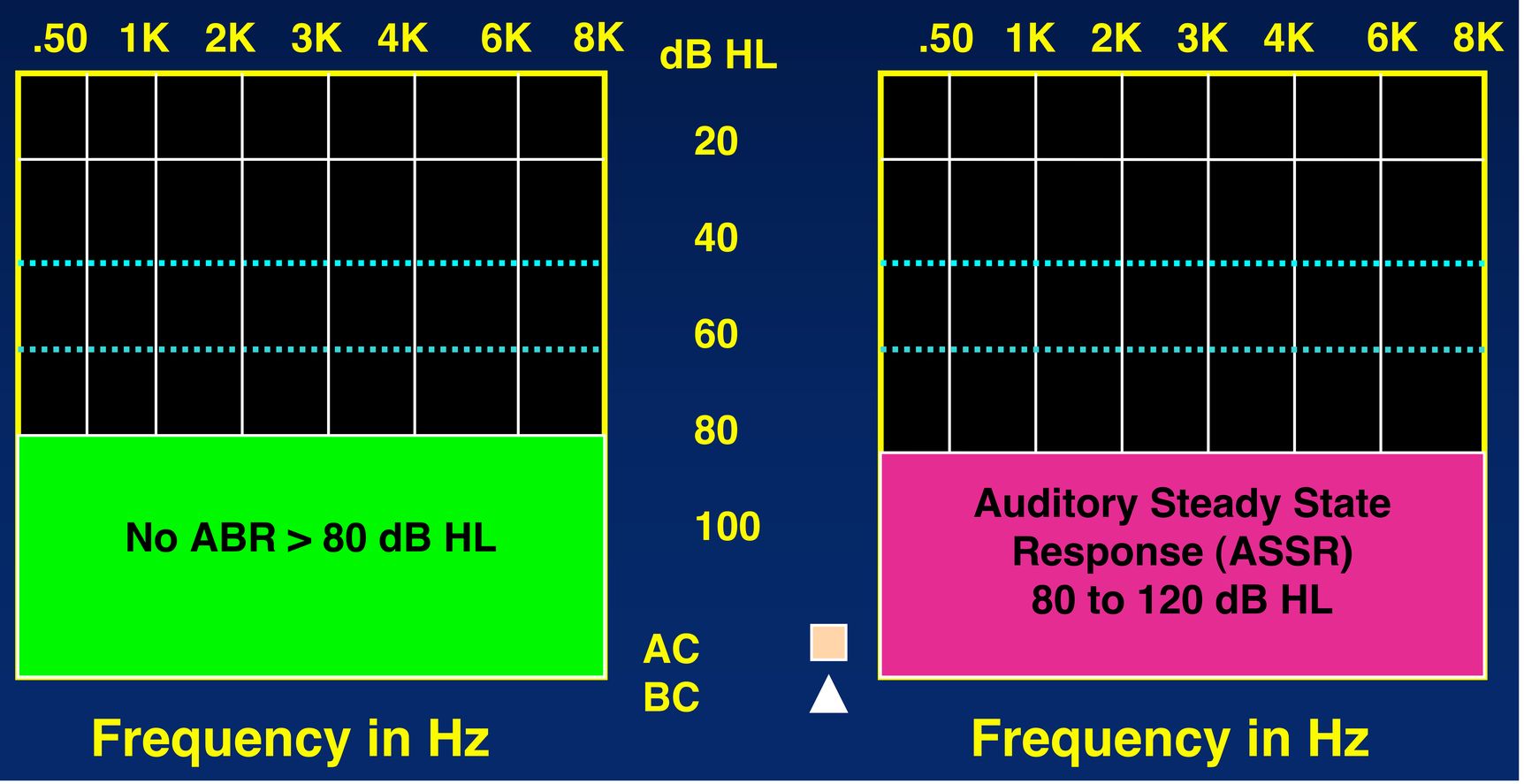
Frequency-Specific ABR Test Protocol: Acquisition Parameters

Parameter	Selection	Rationale
Electrode type	disc & ear-clip disposable	ease of application
Electrode location	Fz - Nape or Ai Fpz ground	optimal infant response good for BC stimulus permits ipsi/contra meas't
Filter settings	30 - 3000 Hz no notch filter	encompass infant spectrum
Artifact reject	on	minimize muscle artifact

Joint Committee on Infant Hearing (JCIH) Position 2000 Statement: Protocol for Confirmation of Hearing Loss In Infants and Toddlers (0 to 6 months)

- Child and family history
- Otoacoustic emissions
- Auditory brainstem response (ABR) with tone burst stimuli to confirm:
  - type
  - degree
  - configuration of hearing loss
- Auditory steady state response (ASSR)??
- Acoustic immittance measures (including acoustic reflexes)
- Behavioral response audiometry *(if feasible)*
  - ✓ Visual reinforcement audiometry *or*
  - ✓ Conditioned play audiometry
  - ✓ Speech detection and recognition
- Parental report of auditory & visual behaviors
- Screening of infant's communication milestones

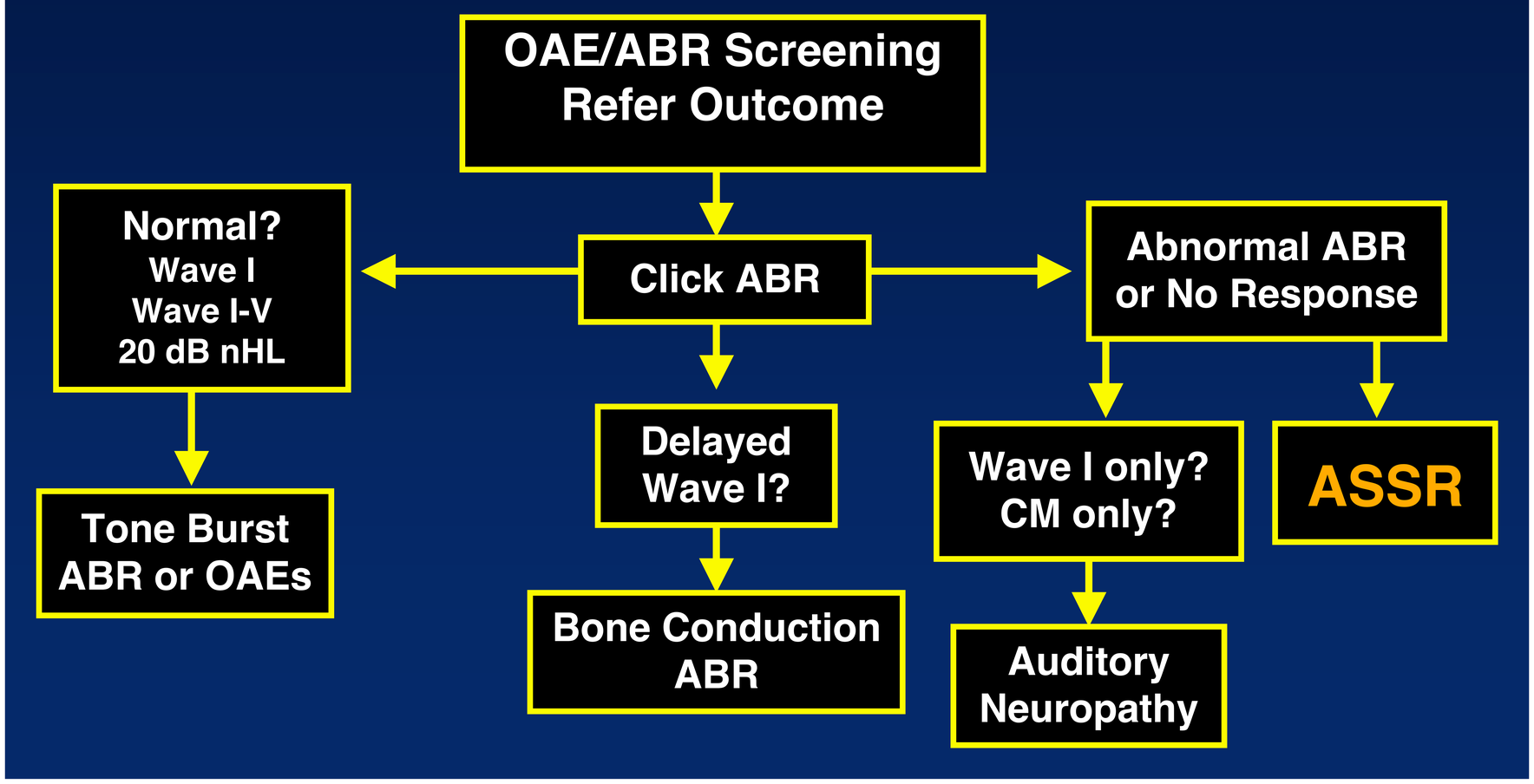
Limitation of Tone Burst ABR in Severe-to-Profound Hearing Loss



Auditory Steady-State Response (ASSR): General Principles

- An electrophysiologic response, similar to ABR.
- Instrumentation includes:
  - Insert earphones
  - Surface electrodes
  - Averaging computer
- Stimuli are pure tones (*frequency specific*, steady state signals) activating cochlea and CNS
- ASSR is generated by rapid modulation of "carrier" pure tone amplitude (AM) or frequency (FM).
- Signal intensity can be as high as *120 dB HL*
- ASSR phase or frequency is detected automatically (vs. visual detection)

Defining the Role of ASSR in Frequency-Specific Estimation of Hearing Sensitivity in Infancy



ASSR: Clinical questions

- Are there maturational effects on ASSR from premature infants through childhood?
- What neuron populations and neurophysiologic principles are important in understanding the ASSR?
- Can ASSR be recorded from non-sedated patients?
- What is the effect of sedation and anesthesia on ASSR?
- How closely correlated are ASSR and pure tone hearing thresholds?
- Can ASSR be used in estimation of *bone conduction* auditory thresholds?
- *How can artifactual ASSRs be avoided with high intensity air- and bone conduction stimulation?*
- Will the ASSR have neuro-diagnostic applications, e.g., detection of retrocochlear dysfunction, dyslexia?

AUDITORY ELECTROPHYSIOLOGY IN AUDIOLOGY TODAY:
Evidence Based Decisions on Clinical Applications

Clinical Application	Electrophysiologic Procedure						
	ECochG	ABR	ASSR	AMLR	ALR	P300	MMN *
Newborn hearing screening	-	+++	?	-	-	-	-
Estimation of audiogram	+	+++	++	-	-	-	-
Neuro-diagnostic assessment							
infants & young children	++	+++	?	+	?	?	?
adults	+	+	?	+	+	+	+
APD assessment	-	+	?	++	++	++	++
Outcome documentation							
cochlear implants	+	+	-	+	++	++	-
auditory training	-	-	-	-	++	++	-

** Limited to laboratory setting at this time*

Literature on Hearing Screening in Elementary School Children

- There are no published investigations of screening for auditory function in kindergarten children (5 years old).
- Auditory function in first grade children (≥ 6 years old)
  - Lyons A, Kei J & Driscoll C. DPOAEs in children at school entry: A comparison with pure-tone screening and tympanometry results. *JAAA 15: 2004* (Univ. of Queensland, Brisbane, Australia)
  - N = 1003 children
  - "When the results of a test protocol which incorporates both DPOAEs and tympanometry were used in comparison with the gold standard of pure tone screening plus tympanometry, test performance was enhanced. The use of a protocol that includes both DPOAEs and tympanometry holds promise as a useful tool in hearing screening of schoolchildren, including difficult-to-test children" (p. 702).

Hearing Screening in Kindergarten Children: Refer Criteria

Screening Procedure	Pass Criteria
Pure tone audiometry	Response at 20 dB HL for 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, and 4000 Hz
Tympanometry	Type A (peak pressure with range of + 50 to - 150 daPa)
Otoacoustic emissions	DP – NF difference > 6 dB at 2K, 4K and 8K)
SSW	Less than 11 errors (< 1 std dev for 20 items) for left ear competing condition

Kindergarten Hearing and Auditory Screening: Pure Tone versus Tympanometry Findings*

	Pure tone Findings	
Tympanometry Findings	Pass	Fail
Pass	192 (70%)	40 ** (15%)
Fail	24 (9%)	17 (6%)

** Pearson Chi-Square significant at $p < 0.01$*

*** None of the subjects at hearing loss on follow up assessment. Difficulty screening a small proportion of kindergarten children also contributed to non-pass outcome.*

Kindergarten Hearing and Auditory Screening: Pure tone versus DPOAE findings*

	Pure tone Findings	
DPOAE Findings	Pass	Fail
Pass	189 (69%)	43 ** (16%)
Fail	27 (10%)	14 (5%)

* *Pearson Chi-Square significant at $p < 0.05$*

** *None of the subjects at hearing loss on follow up assessment. Difficulty screening a small proportion of kindergarten children also contributed to non-pass outcome.*

Hearing Screening of Kindergarten Children: Correlation of outcome for Pure Tone, Tympanometry, and OAE findings (N = 273, right ear data)

	Pure tones							
	500 Hz		1000 Hz		2000 Hz		4000 Hz	
	P	F	P	F	P	F	P	F
Tympanometry								
Pass	205	38**	235	8*	240	3*	240	3*
Fail	21	9	25	5	26	4	26	4
OAEs* **								
Pass	208	41	241	8*	245	4*	245	4*
Fail	18	6	19	5	21	3	21	3

** Significant at $p < 0.01$*

*** Significant at $p < 0.05$*

**** OAE test frequencies were 2000 to 5000 Hz*

Kindergarten Student Hearing Screening: Pure Tone versus Tymp/DPOAE Findings (N = 303)*

	Pure Tone Findings	
Tymp/DPOAE Findings	Pass	Fail
Pass	62%	11%**
Fail	16%	11%

* *Screening outcome for both ears. Relation highly significant.*

** *Includes CNT outcomes and failures at 500 Hz only. No children in this group had peripheral hearing loss.*

Practices Guidelines in Audiology: Identification and Assessment of APD

- "Report of the Consensus Conference on the Diagnosis of Auditory Processing Disorders in School-Aged Children"
- *Journal of American Academy of Audiology 11: 2000.*
  - "APD is broadly defined as a deficit in the processing of information that is specific to the auditory modality."
  - Factors influencing the diagnosis of APD
  - Screening for APD
  - Diagnostic assessment of APD
  - ".. APDs are associated with normal peripheral hearing sensitivity. However, APDs may co-exist with peripheral hearing loss or as a result of conductive hearing loss.
  - "otoacoustic emissions … useful in ruling out inner ear disorders"

Consensus Conference on the Diagnosis of APDs

- Minimal APD test battery
  - behavioral measures
    - ✓ pure tone audiometry
    - ✓ PI functions for word recognition
    - ✓ a dichotic task (digits, words, and/or sentences)
    - ✓ duration pattern sequence test
    - ✓ temporal gap detection
  - electrophysiologic measures
    - ✓ immittance audiometry
    - ✓ otoacoustic emissions
    - ✓ ABR
    - ✓ AMLR
    - ✓ P300 (optional)

Clinical and Research Concerns Regarding the 2000 APD Consensus Report and Recommendations

(Katz et al. Audiology Today 14: 14-17, 2002)

Authors:

Jack Katz
Susan Brandner
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Gail G. Rosenberg
Kim Tillery
Cheryl DeConde Johnson
Teryl Delagrande
John King
Denise Kossover-Wechter
Richard Saul
Nancy Stecker

Clinical and Research Concerns Regarding the 2000 APD Consensus Report and Recommendations

(Katz et al. Audiology Today 14: 14-17, 2002)

Comments about OAEs:

"Research has not substantiated the premise that physiological measures [OAEs] play an important role in typical auditory processing assessment.

"We can find no research studies to suggest that children with APD have a high risk or incidence of inner-ear pathology.

"In fact, for general purposes, pure-tone thresholds reflect cochlear pathology at lower hearing levels than OAEs.

"The recommendation of OAE testing as part of the minimal test battery appears to be without merit."

Reply to "Clinical and Research Concerns Regarding Jerger & Musiek (2000) APD Recommendations

(Jerger J & Musiek F. Audiology Today 14: 19-21, 2002)

- "One important dimension in the differential diagnosis of APD is to differentiate APD from speech understanding problems due to malfunction at either the auditory periphery or the low brainstem level."
- We know that a pure-tone audiogram within "normal limits" does not guarantee normality at the auditory periphery."
- Before you can say that a child's listening problems are due to a disorder in the processing of auditory information at a relatively high level in the central auditory system, it is essential to rule out peripheral disorders at the hair cell level …".
- The best, and virtually only, techniques we current have available for excluding this possibility is evoked OAEs."

Practice Guidelines are (Badly) Needed for APD Assessment and Management

- Clinical indications for APD assessment
- Minimum test battery with procedures for evaluation of major auditory processes including new and improved procedures, e.g.,
  - Gap in Noise (GIN) test for evaluation temporal resolution
- Test procedures that are
  - Age appropriate
  - Auditory specific
  - Sensitive and specific for diagnosis of APD
  - Verbal and non-verbal
- Well researched techniques are needed for management of persons with different patterns of auditory processing disorders, e.g.,
  - Dichotic Intensity Increment Difference (DIID) technique for persons with binaural integration (dichotic) deficits

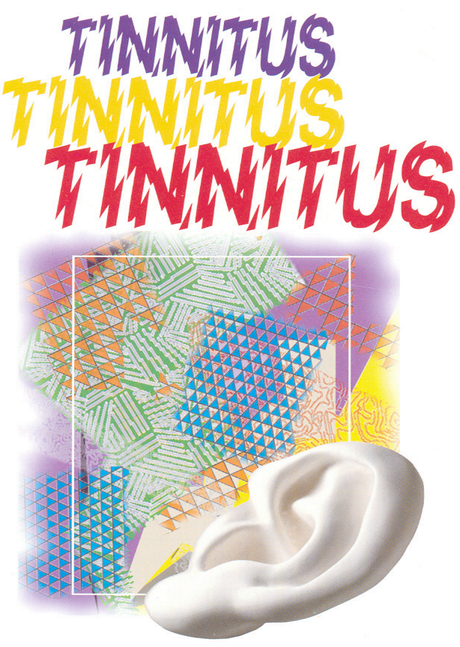
Practices Guidelines in Audiology: Tinnitus Assessment and Management (1)

- Audiologic Guidelines for Diagnosis and Management of Tinnitus (www.audiology.org/professional/positions/tinnitus.php)
- Introduction (background on tinnitus)
- Scope of practice includes tinnitus assessment and management)
- Multi-disciplinary approach recommended
- Suggested evaluation guidelines
  - Comprehensive case history (details provided)
  - Basic audiologic assessment (see other guidelines)
  - Loudness discomfort levels (LDLs)
  - Tinnitus matching
    - ✓ pitch
    - ✓ Loudness
  - Minimal masking level
  - Subjective questionnaires

Best Practices in Audiology Today: Tinnitus Assessment and Management (2)

- Tinnitus patient management procedures
  - Multi-disciplinary approach recommended
  - Counseling
  - Cognitive behavioral therapy
  - Habituation and tinnitus retraining therapy (TRT)
  - Neuromonics technique
  - Hearing aids and tinnitus instruments
  - Maskers and home masking devices
  - *Self-help and support/education groups (problem with guidelines!)*
  - Stress management
  - No evidence to support some alternative treatments, e.g.
    - ✓ Acupuncture
    - ✓ Ginkgo biloba

TINNITUS MANAGEMENT:
Patient Education



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Medical Records:
Reasons for Demise on Actual Death Certificates

- "Went to bed feeling well … woke up dead."
- "Don't know … never fatally ill before."
- "Nothing seriously wrong."
- "Blow to head. (Contributory cause was another man's wife.)"
- "Don't know … died without the aid of a doctor."

Best Practices in Audiology Today *or*
New Ideas About the Old Test Battery

- A trip down memory lane … life in 1946
- Thoughts about standards of care, or guidelines, for audiologic practice
- Good and bad news about clinical guidelines
- Current resources for practice guidelines in audiology
- Examples of some existing practice guidelines
  - children
  - Adults
- A critical review at current test procedures and batteries
- Conclusions and discussion

Best Practices in Audiology Today: Guidelines for Clinical Procedures
(Approach for AAA Task Force on OAE Guidelines)

- Instrumentation
  - equipment requirements, e.g., audiometer specs, CD player for recorded speech materials, tone bursts for ABR, etc)
  - equipment calibration
- Patient selection criteria
  - clinical indications (rationale or justification)
  - clinical contra-indications
- Test protocol, e.g.,
  - test parameters
  - verification of adequate signal and noise conditions
  - requirements and criteria for repeatability
- Analysis procedures and normative data requirements
- Reporting OAE findings

A few suggested assumptions about about procedures in test batteries *or* New Ideas About the Old Test Battery

- In the assessment of an individual patient, an audiologic procedure must
  - have adequate test performance
    - ✓ sensitivity
    - ✓ specificity
    - ✓ validity
    - ✓ reliability
  - be time efficient (versus alternative tests)
  - offer sufficient benefit versus cost ratio (versus alternative tests)
  - add value to the diagnosis of auditory dysfunction
  - contribute to management of the patient
  - enhance patient outcome

Best Practices in Audiology Today; Principles of Procedures (Why perform an audiologic procedure?)

- Value added tests (VATs)
  - the procedure adds value to the description of auditory status for the patient … information that's
    - ✓ not available from other procedures,
    - ✓ obtained quicker than with another procedure
    - ✓ useful in managing the patient
- OAEs are an example of a VAT
- Some traditional procedures do *not* invariably add value
  - SRT
  - bone conduction pure tone audiometry
  - word recognition in quiet at 40 dB SL

The Audiology Test Battery Today: How far have we come after 60 years of clinical research and experience?

Procedure	% performing procedure
Pure tone audiometry: air conduction	100%
Pure tone audiometry: bone conduction	100%
Word recognition	95%
Speech reception threshold	91%
UCL (LDL) for speech	83%
Tympanometry	45%
UCL (LDL) for tones	45%
Acoustic reflexes	20%
Otoacoustic emissions (OAEs)	4%

Source: The Hearing Journal, December, 2002

Best Practices in Audiology Today *or*
New Ideas About the Old Test Battery

- Bone conduction measures … not always indicated or a good use of clinical time and money.
- Patient selection criteria or clinical indications *for* bone conduction measurement?
  - history of middle ear disease
  - abnormal otoscopic findings
  - abnormal aural immittance findings
- Bone conduction pure tone audiometry is *not* indicated with
  - negative history of middle ear disease/dysfunction
  - normal otoscopic findings
  - normal tympanometry and acoustic reflex
  - normal OAEs (including low frequencies)

Best Practices in Audiology Today *or*
New Ideas About the Old Test Battery

- Hall JW III. Page Ten: Clinical challenges of bone-conduction measurement. *The Hearing Journal 58*: 10-15, 2005 (AAA convention issue)
  - Is bone conduction testing still necessary?
  - How can we solve the masking dilemma?
  - A review of the SAL technique
  - Role of the audiometric Weber test
  - Bone conduction ABR measurement
  - Bone conduction ASSR measurement

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Otoacoustic emissions (OAEs)	4%

Source: The Hearing Journal, December, 2002

Best Practices in Audiology Today *or*
New Ideas About the Old Test Battery

- Speech reception threshold … to do or not to do?
  - questions about a sacred cow in clinical audiology
  - making an evidenced based decision
- Word recognition … how and how much?
  - which speech materials?
  - mode of delivery (recorded vs. MLV)?
  - at what intensity level (s)?
  - how many words (what about 10 most difficult words first?)
- When do we do more than word recognition in quiet?
  - words in the presence of background noise?
  - sentence speech materials in noise, e.g., HINT or SSI-ICM
  - APD speech procedures, e.g., dichotic listening tests?

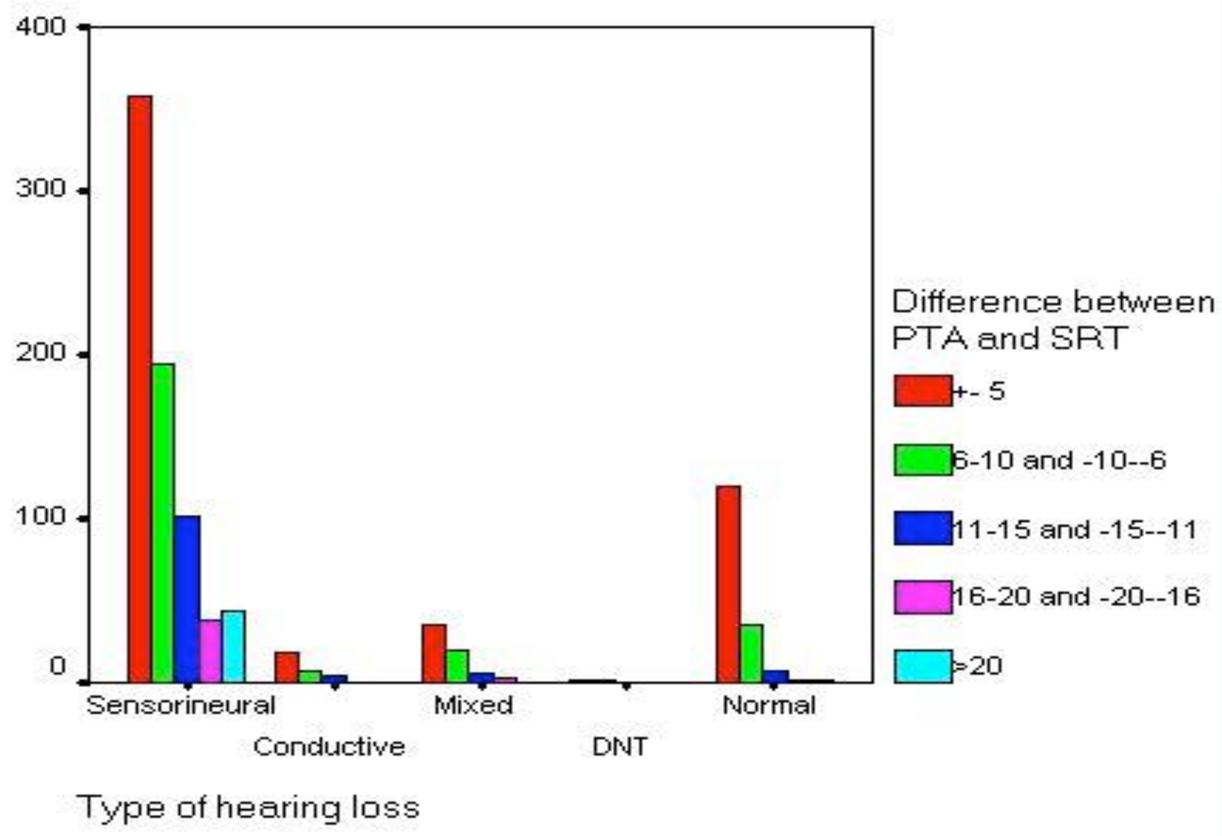
A New Look at an Old Test (SRT)

Emily Roscher and JW Hall III

- 2005 NAFDA convention poster
- Email survey of random sample of clinical audiologists
  - 90% routinely perform SRT measurement
  - 53% routinely calculate pure tone average
  - criteria for an acceptable PTA vs. SRT difference ranged from 5 to 12%
- N = 1000 subjects
  - Age 2 to 92 years
  - 570 males (57%) and 430 (43%) females
- Hearing loss
  - 74% sensorineural
  - 16% normal
  - 6% mixed
  - 3% conductive

New Ideas About an Old Test: Speech Reception Threshold

Roscher & Hall, 2005



A New Look at an Old Test (SRT)

Emily Roscher and JW Hall III

- Significant differences between PTA vs. SRT (significant portion of subjects > +/- 5 dB) were related to selected factors
  - age
    - ✓ children (< 20 years) vs. adults 20 to 66 years
    - ✓ older adults (> 66 years) vs. adults 20 to 66 years
  - hearing loss
    - ✓ greater PTA-SRT difference for sensorineural vs. normal
    - ✓ greater PTA-SRT difference for sloping hearing loss vs. normal hearing
- No significant difference between PTA and SRT for
  - gender

A New Look at an Old Test: Preliminary Conclusions

- SRT findings are related to age and hearing status
  - 94% of normal hearing subjects (≤ 20 dB) had PTA vs. SRT difference of < +/- 10 dB)
  - PTA vs. SRT difference was smallest in subjects aged 20 to 66 years
- Conclusion
  - Routine SRT measurement is not necessary in normal hearing young adults
  - Depending on patient population, discontinuance of routine SRT measurement will yield considerable savings in time and hearing health care cost

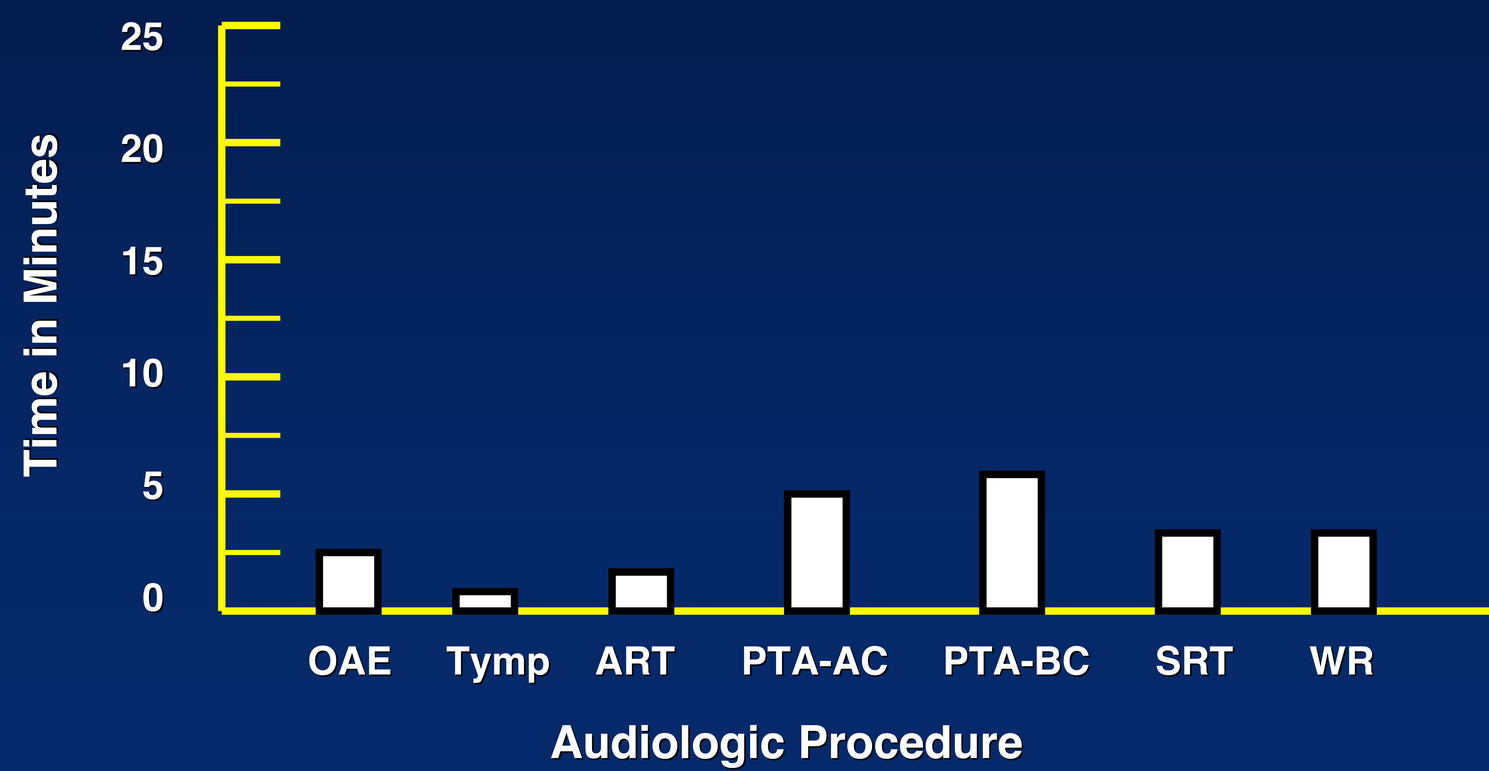
Comparative Test Times for Different Combinations of Audiologic Procedures

"Remember that time is money"

Benjamin Franklin

Advice to a Young Tradesman
1748

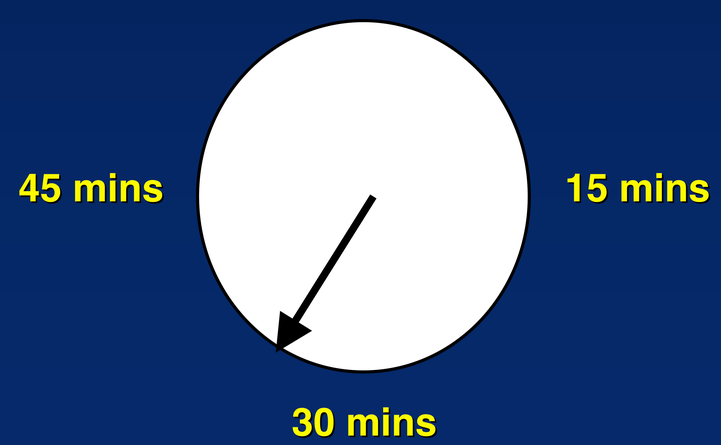
Comparative Test Times for Selected Audiologic Procedures (both ears with masking as indicated)



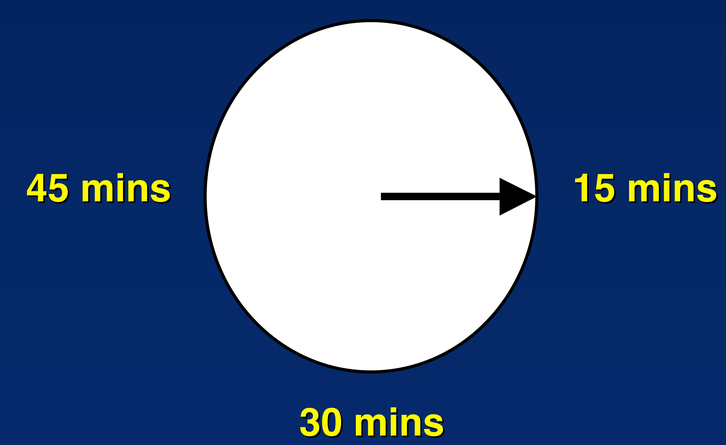
Comparative Test Times for Different Combinations of Audiologic Procedures (both ears with masking as indicated)

Audiologic Procedures in Two Basic Test Batteries

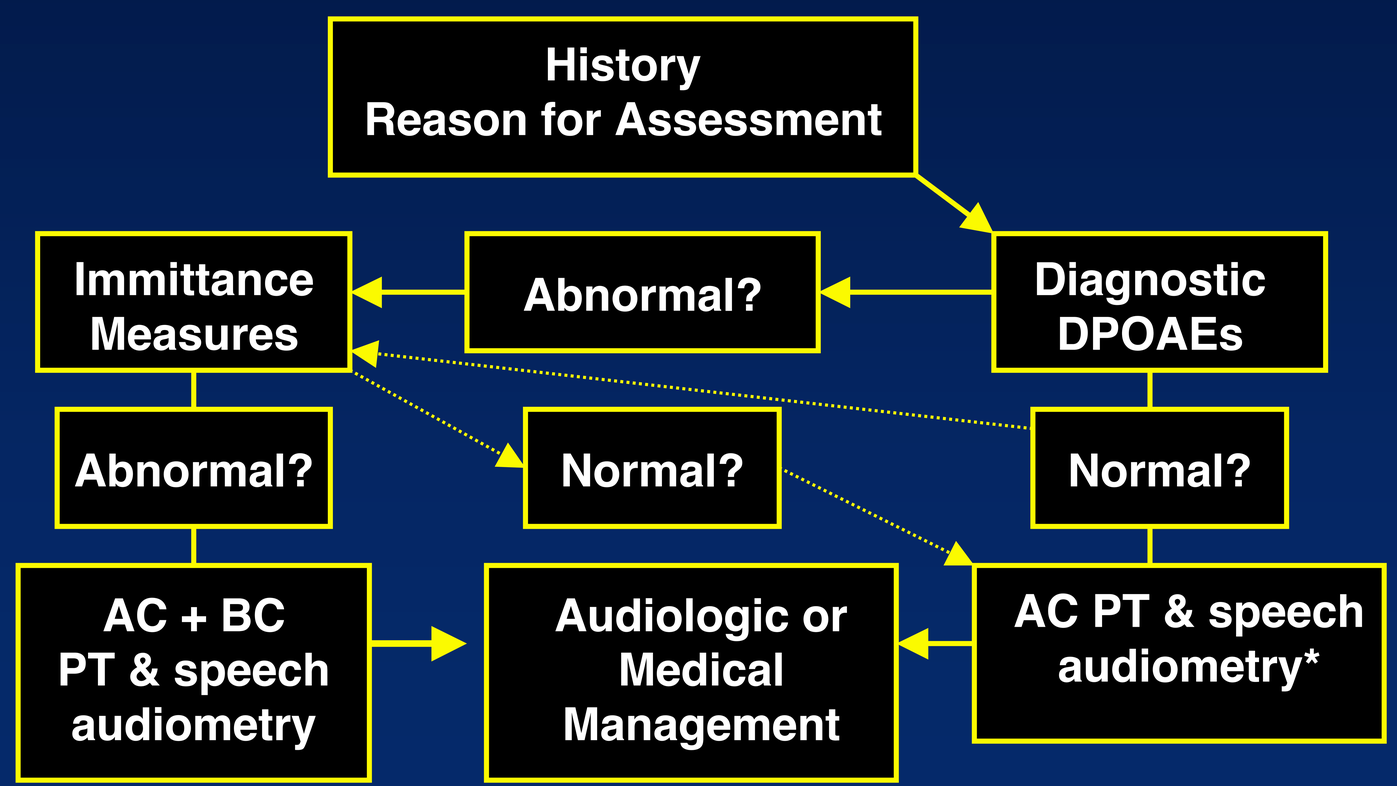
PTA-AC
PTA-BC
SRT
WR (25 word lists)



OAE
Tymp
PTA-AC
WR (10 most difficult words 1st)



Best Practices in Audiology Today: Initial Steps in the Assessment



** SRT as indicated; WR 10 most difficult words*

Let's take an unsentimental look at our test battery before we institutionalize it into practice guidelines!

Procedure	% performing procedure
Pure tone audiometry: air conduction	100%
Pure tone audiometry: bone conduction	100%
Word recognition	95%
Speech reception threshold	91%
UCL (LDL) for speech	83%
Tympanometry	45%
UCL (LDL) for tones	45%
Acoustic reflexes	20%
Otoacoustic emissions (OAEs)	4%

Source: The Hearing Journal, December, 2002

Protocols in Audiology

Plural Publishing Company

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

- Protocols for all audiologic procedures based on evidence generated from clinical research
- Historical overview of each procedure
- Concise description of current and state-of-the art techniques
- Step-by-step overview of procedures

Protocols in Audiology

Plural Publishing Company

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

- Otoscopy
- Case history
- Basic audiology, e.g.,
  - Pure tone audiometry
    - ✓Air-conduction thresholds
    - ✓Bone-conduction thresholds
    - ✓Special tests (e.g., SAL, Weber, etc)
  - Speech audiometry
    - ✓Speech reception threshold
    - ✓Word recognition
    - ✓Speech perception in noise/competing message

Protocols in Audiology

Plural Publishing Company

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

- Diagnostic Audiology, e.g.,
  - Otoacoustic emissions
  - Aural immittance measures
  - Auditory electrophysiology in infants and young children
  - Auditory brainstem response
  - Cortical auditory evoked responses
- Vestibular and balance assessment, e.g.,
  - ENG
  - VEMP
  - Posturography

Protocols in Audiology

Plural Publishing Company

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

- Pediatric populations
  - Peripheral hearing loss
    - ✓Diagnosis
    - ✓Amplification
    - ✓Cochlear implants
  - Auditory processing disorders
    - ✓Diagnosis
    - ✓Management
  - Ototoxicity monitoring
  - Auditory neuropathy
    - ✓Diagnosis
    - ✓Management

Best Practices in Audiology Today *or*
New Ideas About the Old Test Battery
Conclusions …

- Practice guidelines are rapidly expanding
- Many questions remain unanswered about
  - ✓the benefits of guidelines for patients
  - ✓the impact of guidelines on the quality of healthcare
  - ✓potential financial and professional abuse of guidelines
- The audiologic test battery needs to be updated
  - ✓focus on procedures that add value to outcome
  - ✓incorporation of more efficient test strategies, e.g., adaptive procedures
- Questions, Answers and Discussion …