HEARING TESTS AND MEASUREMENT
Audiology and Speech Language Pathology 438 (3.0 credits)
David L. McPherson, Ph.D. - 129 TLRB
378-6458 (office) - 375-9166 (home)

This syllabus was compiled in part by
Julie Michaelis, Graduate Student
& Stefani Lee, Graduate Student
1995-1998

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ADVICE TO STUDENTS

If you learn the principles you will understand the details and remember the facts

In other words

Don’t paint by numbers and ignore the lines
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HEARING TESTS AND MEASUREMENT
Audiology and Speech Language Pathology 438 (3.0 credits) - Fall 1997
Monday, Wednesday & Friday - 9:00am - 9:50am - 177 TLRB
David L. McPherson, Ph.D. ¹ - 129 TLRB
378-6458 (office) - 375-9166 (home)

Course Description
This course is required for undergraduate students majoring in Audiology and in Speech-Language Pathology. This course meets the American Speech-Language-Hearing Association's (ASHA) certification requirements for course work in assessment and pathologies of the auditory system.

This course presents primary skill development in the administration and interpretation of basic tests of auditory disorders including pure tone air- and bone conduction threshold testing; speech audiometry; fundamentals of middle ear tympanometry; and school and industrial hearing screening. Anatomy and physiology of the normal and pathological auditory system are introduced.

Prerequisites
The following courses are required prerequisites: ASLP 334 and Physics 167. Students that have not completed these prerequisites are required to discontinue this course until such time the prerequisite courses have been completed.

Honor Code
The student is expected to be familiar with the Honor Code. The Honor Code is enforced in this class and students will be required to conform to its principles and practices. Cheating and plagiarism may result in a class failure, at the discretion of the instructor.

Course Meeting Times
This is a 3 credit course scheduled to meet Mondays, Wednesdays, and Fridays. Normally Fridays will be used as a laboratory class to demonstrate equipment and techniques.

Course Objectives
A. To develop a theoretical and practical knowledge of hearing tests and measurements in the field of communicative disorders.
B. To become proficient in the administration of standard audiological testing in adults and children.
C. To understand the role of audiology in auditory and speech-language disorders.
D. To gain the fundamentals of gathering case history information and report writing.

Textbooks (required)

¹Office hours by appointment only.
will be referred to in other audiology courses, and for speech-language majors it is a valuable resource.]

**COURSE REQUIREMENTS**

**Examinations**
There will be two examinations, a midterm (30pts) and a final (30pts). They will be essay or short answer type. Additional points on each question may be awarded for exceptional answers without penalizing other students. Students are encouraged to meet with the instructor following the midterm examination to discuss each question/answer. Examinations are given as scheduled.

**Quizzes**
There will be five quizzes worth 4 pts each. These will be similar to the explanations given above for the midterm and final examination. Quizzes are given as scheduled.

**Course Participation**
The student is expected to be prepared. This includes having read the material prior to class. Students that are not prepared may be penalized one point for each class period. Absence from class is considered unprepared except for medical purposes.

---

\(^2\)All assignments must be typewritten unless otherwise noted. If computer generated, an easily readable font must be used. Originals and copies must be clear with dark print. Unless otherwise noted all assignments are due by the beginning of the class period (9:10 am) on the due date. Penalties are assigned for late assignments which amount to 20% of the total earned for that assignment.
Laboratory Assignments

There will be five laboratory assignments worth 2 points each. These will be practical experiences in audiometric assessment. The audiometers may be checked out from the secretary in room 136 TLRB, during posted office hours. Speech audiometry will not be required because of the limited space in the audiological testing suites. Assignments 3, 4, and 5 will require the use of room 122 TLRB which has both a portable audiometer and a screening tympanometer. A sign-up sheet is located on the door. Additionally, the tympanometry may be completed in room 116 TLRB and any other therapy room may be scheduled for the audiometric testing (you will have to schedule a portable audiometer).

<table>
<thead>
<tr>
<th>Assignment no.</th>
<th>Topic</th>
<th>Due</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Three pure tone air conduction audiograms (no masking required).</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Three pure tone air- and bone-conduction audiograms (use ear plug in one ear to simulate a conductive hearing loss and use proper masking procedures).</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Two impedance evaluations (tympanometry, acoustic reflex) along with the pure tone audiogram (air- and bone-conduction).</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>One pediatric (3-5 year old) audiometrics with tympanometry.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>One complete work-up with history.</td>
<td></td>
</tr>
</tbody>
</table>

Term Paper

Each student will be required to submit an eight to ten page term paper that will be weighted to 10% of the final grade (i.e., 10 points). It will be typed according to the American Psychological Association's style manual (available at the bookstore/library). Since you are entering a profession where timeliness is of the essence in patient care, late papers will not be accepted. APA style will be required. Term papers done in other classes may NOT be used to complete this assignment. The only exception are those that are completing the technical writing assignment in English.

Suggested topics for term papers: The topic for term papers must be approved by the instructor. The following are suggested topics, but are not all inclusive. The cover sheet at the end of this syllabus MUST be the first page of your term paper. Term papers are NOT to have hard covers and MUST be securely fastened with staples or other permanent fasteners. Do not use “sliding” fasteners.

---

3It is your responsibility to make an appointment with the instructor to discuss the topic and get approval for the term paper topic.
Age related hearing loss on the effects of speech production
Behavioral development of the auditory system
Disease factors causing hearing loss
Effects of aging on hearing
Effects of hearing loss on language development
Genetic hearing loss
Hearing loss in infancy
Localization and hearing
Neurologic insults on hearing
Noise induced hearing loss
Ototoxic hearing loss
Speech communication in noise
The effects of the classroom environment on the hearing impaired

<table>
<thead>
<tr>
<th>Grading Criteria</th>
<th>Points</th>
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<tbody>
<tr>
<td>Relevance of Topic &amp; topic approval</td>
<td>0.5</td>
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<tr>
<td>Style (APA)</td>
<td>1</td>
</tr>
<tr>
<td>Clarity of writing</td>
<td>2</td>
</tr>
<tr>
<td>References</td>
<td>1.5</td>
</tr>
<tr>
<td>Depth of content</td>
<td>2.5</td>
</tr>
<tr>
<td>Quality of Content</td>
<td>2.5</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>10</strong></td>
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</table>
Grading Standard

Each of the above areas will be weighted for a total of 100 points. Cheating results in class failure.

<table>
<thead>
<tr>
<th>Assignment</th>
<th>Points</th>
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</thead>
<tbody>
<tr>
<td>Final examination</td>
<td>30 pts</td>
</tr>
<tr>
<td>Midterm examination</td>
<td>30 pts</td>
</tr>
<tr>
<td>Five quizzes</td>
<td>20 pts</td>
</tr>
<tr>
<td>Five laboratory assignments</td>
<td>10 pts</td>
</tr>
<tr>
<td>Term paper</td>
<td>10 pts</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100 pts</td>
</tr>
</tbody>
</table>

<table>
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<tbody>
<tr>
<td>A</td>
<td>96-100 pts</td>
<td>C+</td>
<td>78-80 pts</td>
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<tr>
<td>A-</td>
<td>92-95 pts</td>
<td>C</td>
<td>75-77 pts</td>
</tr>
<tr>
<td>B+</td>
<td>88-91 pts</td>
<td>C-</td>
<td>70-74 pts</td>
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<tr>
<td>B</td>
<td>84-87 pts</td>
<td>D</td>
<td>65-69 pts</td>
</tr>
<tr>
<td>B-</td>
<td>81-83 pts</td>
<td>E</td>
<td>64 &amp; below</td>
</tr>
</tbody>
</table>
## COURSE SCHEDULE AND OUTLINE

### HEARING TESTS AND MEASUREMENT

Audiology and Speech Language Pathology 438

<table>
<thead>
<tr>
<th>Class Number</th>
<th>Date of Class</th>
<th>Lecture topic</th>
<th>Assignments</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31 Aug</td>
<td>Introduction to Audiology, the Audiogram, and the Audiometer</td>
<td>Pages 190-191 “Case History”</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2 Sep</td>
<td>Psychoacoustics for Audiology</td>
<td>Chap 5</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>4 Sep</td>
<td>Syllabus &amp; Orientation</td>
<td>Chap 1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>9 Sep</td>
<td>Fundamentals of Puretone testing I: Pediatric techniques</td>
<td>Chap 7</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>11 Sep</td>
<td>Fundamentals of Puretone testing II</td>
<td>Chap 7</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>14 Sep</td>
<td>Demo 1: Puretone testing: Air conduction testing*: Part I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>16 Sep</td>
<td>Demo 1: Puretone testing: Air conduction testing*: Part II</td>
<td></td>
<td></td>
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<tr>
<td>8</td>
<td>18 Sep</td>
<td>Hearing Screening I: Newborn to 3 years of age.</td>
<td>Chap 30</td>
<td>Quiz 1 (Classes 1-7)</td>
</tr>
<tr>
<td>9</td>
<td>21 Sep</td>
<td>Hearing Screening II: School age.</td>
<td>Chap 31</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>23 Sep</td>
<td>Hearing Screening III: Community (noise, geriatric, workplace).</td>
<td>Chap 35 Know what the term OSHA means and its main function</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>28 Sep</td>
<td>Demo 2 (cont.): Video Otoscopy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>30 Sep</td>
<td>Demo 2: Case history and otologic inspection</td>
<td></td>
<td></td>
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<tr>
<td>14</td>
<td>2 Oct</td>
<td>Immittance Audiometry I: Theory of Immittance audiometry and tympanometry</td>
<td>Chap 19</td>
<td></td>
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<tr>
<td>15</td>
<td>5 Oct</td>
<td>a. Immittance Audiometry III: Acoustic reflex testing.</td>
<td>Chap 20, 21</td>
<td></td>
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<tr>
<td>16</td>
<td>7 Oct</td>
<td>Demo 3: <em>Tympanometry</em> Demo 4: Acoustic reflex testing.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>9 Oct</td>
<td>ASHA Guidelines in Audiology</td>
<td>ASHA Handout in syllabus</td>
<td>a. These you MUST know</td>
</tr>
<tr>
<td>18</td>
<td>12 Oct</td>
<td>Theory of bone conduction I</td>
<td>Chap 8</td>
<td>Quiz 2 (classes 8-14) Don’t worry about formulas</td>
</tr>
<tr>
<td>19</td>
<td>14 Oct</td>
<td>Theory of bone conduction II</td>
<td>Chap 9</td>
<td>Quiz 2 (Theory of puretone testing).</td>
</tr>
<tr>
<td>20</td>
<td>16 Oct</td>
<td>Demo 5: Puretone testing: Bone conduction</td>
<td>Lab 1 due.</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>19 Oct</td>
<td>Puretone bone conduction testing. Masking I: Theory of clinical masking</td>
<td>Chap 8 &amp; 9 Clinical Masking handout</td>
<td>In syllabus</td>
</tr>
<tr>
<td>22</td>
<td>21 Oct</td>
<td>Masking II: Masking of air conduction puretone testing</td>
<td>Chap 8 &amp; 9 Clinical Masking handout</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>23 Oct</td>
<td>Demo 6: Masking air and bone conduction.</td>
<td></td>
<td></td>
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<tr>
<td>24</td>
<td>26 Oct</td>
<td>Masking: Review</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>28 Oct</td>
<td>MID TERM EXAMINATION</td>
<td></td>
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</tr>
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*Worksheets located for these demonstrations in the back of the syllabus.

*Reading assignments are to be completed prior to the beginning of the class period.
## COURSE SCHEDULE AND OUTLINE, cont'd

**HEARING TESTS AND MEASUREMENT**  
Audiology and Speech Language Pathology 438

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<th>Date of Class</th>
<th>Lecture topic</th>
<th>Assignments</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>30 Oct</td>
<td>Masking III: Masking of bone conduction puretone testing</td>
<td>Chap 8 &amp; 9 Clinical Masking handout</td>
<td>Quiz 3 (Theory of masking).</td>
</tr>
<tr>
<td>27</td>
<td>2 Nov</td>
<td>Masking IV: Masking Problems</td>
<td>Chap 8 &amp; 9 Clinical Masking handout</td>
<td>Lab 2 due</td>
</tr>
<tr>
<td>28</td>
<td>4 Nov</td>
<td>Speech Audiometry I: Threshold Testing</td>
<td>Chap 10</td>
<td>Differences between SRT and SDS</td>
</tr>
<tr>
<td>30</td>
<td>9 Nov</td>
<td>Speech testing II: Speech Discrimination Testing</td>
<td>Chap 10</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>13 Nov</td>
<td>Demo 8: Auditory Evoked Potentials.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>16 Nov</td>
<td>Otoacoustic Emissions</td>
<td>Chap 29 Skim</td>
<td>Know what they are, but not required to know the testing procedures. Use study questions to guide reading.</td>
</tr>
<tr>
<td>34</td>
<td>18 Nov</td>
<td>Tests of Cochlear Function</td>
<td>Chap 11, 12 Chap 13 Know HR and FAR Chap 28 pp. 424-430, 442-4</td>
<td>a. Lab 4 due b. Know what they are, but not required to know the testing procedures.</td>
</tr>
<tr>
<td>35</td>
<td>20 Nov</td>
<td>Demo 9: Otoacoustic Emissions</td>
<td></td>
<td>Quiz 5 (Classes 28-34)</td>
</tr>
<tr>
<td>36</td>
<td>23 Nov</td>
<td>Disorders of the Central Auditory Nervous System</td>
<td>Chap 14 pp. 197-200, 205-8 Chap 15 pp. 212-13 Chap 16 pp. 222-23 Chap 17 and 18 (Know test names and clinical uses)</td>
<td>Know what they are, but not required to know the testing procedures.</td>
</tr>
<tr>
<td>37</td>
<td>30 Nov</td>
<td>Special populations (pediatrics, geriatrics, special needs)</td>
<td>Chap 34, 39</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>2 Dec</td>
<td>Hearing Aids</td>
<td>Readings ?</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>4 Dec</td>
<td>Cochlear Implants &amp; Assistive Listening Devices</td>
<td>Readings ?</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>7 Dec</td>
<td>Aural Rehabilitation</td>
<td>Readings ?</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>9 Dec</td>
<td>TBA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>10 Dec</td>
<td>Review</td>
<td></td>
<td>a. Last day for late or make-up assignments. b. Lab 5 due.</td>
</tr>
<tr>
<td>17 Dec</td>
<td>FINAL EXAMINATION 11:00 am - 2:00pm</td>
<td>Room 177 TLRB</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Worksheets located for these demonstrations in the back of the syllabus.*
SAMPLE LABORATORY ASSIGNMENT

LABORATORY ASSIGNMENT #1

(Student name)
(Course)
(Date)

Laboratory Assignment: Puretone audiogram

Puretone audiograms (three) were completed on other students that were reported to have normal hearing. A portable audiometer (Beltone 10C) was used. The testing was done in a quiet room. Both air- and bone-conduction audiograms were constructed from the results.

Note: The student must attach copies of each audiogram and/or other forms (stapled) to the cover sheet.
SAMPLE CASE HISTORY AND REPORT

AUDIOLOGIC EVALUATION

(Student name)
(Course)
(Date)

Patient Name: Clyde Gates
Date of Birth: 15 June 1956
Sex: Male  Age: 35 years

Date of Evaluation: December 7, 1991

Complaint
The patient reported that he was unable to hear people when he was in a noisy situation and his wife complained the television was too loud. Also it was stated that he had a 'hissing' in his ears at times that sounded like 'a steam valve was broken.' He noted that although he can 'hear' people it is difficult to understand what they are saying.

Background
The patient has a negative history for familial hearing loss, acute illnesses resulting in fevers or the use of antibiotics, and states he is in general good health. The patient is employed as a pipe fitter and works in a situation that he described as 'high' noise level. The patient reported no significant history of high blood pressure, cardiac disease and is a non-smoker. The patient drinks alcohol on social occasions. The patient enjoys SCUBA diving and reports frequent ear infections. He also reported having difficulty clearing his ears on moderate to deep dives. The patient reported he did not experience any dizziness or gait problems.

Clinical Observation
Speech and language appear normal for age and social conditions. No phonemic regression was noted. The patient understood all of my questions when facing him, but on a couple of occasions had difficulty understanding me if my face was turned in a different direction. It is my impression he relies on speech reading to supplement his auditory cues.

Evaluation
[A description of the tests/evaluation used would be placed in narrative with a summary description of the results. For example]:

Puretone air- and bone-conduction thresholds under appropriate masking procedures suggest a 50 dB loss in the low-to-mid- frequencies sloping to a severe loss in the mid-to-high frequencies (70-90 dB), with an air-bone gap in the 250-2000 Hz range.
Speech recognition thresholds were consistent with the puretone audiogram. Speech discrimination, in quiet, showed 66% on the right and 48% on the left.

Tympanometry showed reduced compliance, bilaterally. The acoustic reflex could not be elicited except in the right ear at 4000 Hz using maximum intensity (110 dB SPL).

**Impression**

A true estimate of residual hearing abilities in this patient could not be established because of possible middle ear involvement as noted by the abnormal tympanograms, bilaterally. However, it is my guess that there is probably a moderate-to-severe hearing loss present. The history would indicate the presence of tinnitus. Although the actual etiology cannot be established this patient's profile is typical of noise induced permanent hearing loss and/or barotrauma.

**Recommendations**

1. Medical referral for both possible intervention and hearing aid clearance.
2. Repeat threshold testing following medical intervention.
3. Tinnitus evaluation.
5. Counseling as to ear defenders and the use of such.
7. Communicative strategy counseling with the spouse.

The patient was counseled as to the above recommendations and has agreed to follow-up. I would very much like receiving copies of any reports and will be responsible for the audiological management of this patient.

*(Signature)*

David L. McPherson, Ph.D.

attachments: Audiogram, tympanograms
cc: Chart files
SAMPLE ESSAY EXAM QUESTION

Blue books, using double spacing, are to be used in all examinations except for 'take home' examinations that are to be typewritten, double spaced.

(Student name)  
(Course)  
(Date)

Exam question: Describe and characterize the measures used in the auditory brainstem evoked potential recording and their relationship to stimulus intensity.

Response: The auditory brainstem evoked potential may be described as a biphasic waveform with quantitative properties of amplitude and latency. In addition a qualitative feature may be described in terms of its morphology.

Amplitude may either be described in voltage, usually microvolts, from the baseline to corresponding peak, or from positive peak to corresponding negative peak. As stimulus intensity increases, the amplitude of the response increases. The converse is also true. The first amplitude changes from baseline, in ideal recording conditions, may be seen as early as 10 dB above behavioral threshold for the stimulus; especially sharply rising (i.e., clicks) stimuli.

Latency is defined as the time, in milliseconds, from the onset of the stimulus to a peak. For consistency, wave V, which may be broad, is defined as the breaking point, or departure point, from the linear descending slope. Latency decreases as stimulus intensity increases. The converse is also true.

It should be noted that there is a point where both amplitude and latency asymptote.

In formulating this question one point is awarded for each correct identification and discussion of the pertinent areas:

1. Description of amplitude
2. Description of latency
3. Description of morphology
4. Use of microvolts
5. Use of milliseconds
6. Relationship of amplitude to intensity
7. Relationship of latency to intensity
8. Statement of how amplitude is measured
9. Statement of how latency is measured
10. Relationship of amplitude and latency to morphological features

It should be noted that areas 1, 2, 4, 5, 6, 7 and 8 were covered providing 7 points for this answer. However additional discussions in some areas were significant enough that extra points were awarded:

1. Acknowledging that the response is biphasic.
2. Amplitude may be measured using one of two references.
3. Amplitude of a wave may first appear at about 10 dB SL. Consequently, an additional three points are awarded for this question providing a total of 10 points. Such additional points are solely at the discretion of the instructor. Since a grading curve is not used, other students are not penalized.
SAMPLE APA STYLE PAPER

Running head: COCHLEAR IMPLANTS FOR CHILDREN

Cochlear Implants for Deaf Children:

A Guide for Parents

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Abstract

Cochlear implants are defined. Eligibility for cochlear implants are discussed, including factors such as: Degree of hearing loss, physical structures present, and age of onset. The advantages and disadvantages are discussed in terms of the aforementioned factors. Rehabilitational factors are explored, and differences in types of rehabilitation are shown to have a significant impact on successful communication for implant wearers.
Cochlear Implants for Deaf Children:

A Guide for Parents

In recent years, technological advances have made it possible for persons with profound hearing impairments to benefit from certain types of amplification. Of these advances, the most notable has been the cochlear implant for the profoundly hearing impaired. Otolaryngologists (ear, nose, and throat doctors) and audiologists have explored the advantages and disadvantages of such devices and agree that the cochlear implants are mostly beneficial. However, some controversy over the effects of the implant have made parents of deaf children wary of the devices. The concerns of parents warrant investigation of the positive and negative effects of cochlear implants.

What is a Cochlear Implant?

A cochlear implant is a device that is worn both externally and internally deep inside the skull. Figure 1 shows a schematic diagram of the Nucleus cochlear implant. The implant works briefly like this: First, sound enters the system through the microphone, which rests behind the individual's ear, much like a hearing aid. The sound is then sent from the microphone through a thin cord to the speech processor. The processor selects sounds most useful for speech/sound recognition. The codes are sent back through the same cord to the transmitter coil, which sends the codes across the skin to the internal processor via the internal coil. The internal processor converts the codes into electrical signals and sends them along the electrical array implanted in the cochlea. For the Nucleus cochlear implant, twenty-two electrodes are arranged along a narrow piece of flexible tubing. Each electrode is connected, by a wire, to the internal processor. The coded electrical signal is delivered to specific electrodes, each of which is programmed separately and can deliver signals at varying intensities and pitches. The electrodes stimulate different hearing nerve fibers, which send the messages to the brain for interpretation (Cochlear, 1990). Most cochlear implants work in similar fashion, but the Nucleus
cochlear implant uses the most complex technology to date (Horn, Nozza, & Dolitsky, 1991) and will be the main focus in this research.

What Factors Define Eligibility for Cochlear Implants?

Because cochlear implants are so successful, several professionals believe that the only criterion for receiving one is possession of profound deafness. However, this is not true (Tyler, 1993). Cochlear implants are only available to a select few individuals who have the necessary background and traits required for the procedure. The first thing to consider when choosing a candidate is the degree of hearing loss the individual suffers from.

Degree of Hearing Loss

"The child must exhibit a severe to profound hearing loss. In addition, the child must not benefit significantly from hearing aids or other conventional amplification devices" (Horn, Nozza, & Dolitsky, 1991, p. 83). The degree of hearing loss is measured in decibels (dB) on various frequencies. To be severely hearing impaired, at least an average hearing loss of +70 dB would be exhibited. Profound deafness begins at the average of +90 dB. Normal hearing is anywhere between -10 and +25 dB (Bess & Humes, 1990). Some severely deafened children and adults can still hear with conventional hearing aids. Those people would not be considered for implantation since the hearing gained from the implant may be less than what they already hear from a hearing aid.

Physical Structures

The second consideration for the success of the cochlear implant depends upon the existing physical structures within the potential recipients ear. There are numerous causes of deafness that can usually be broken down into three categories: Inheritance, congenital complications, or disease. Usually with inherited deafness and congenital complications, the ear ossicles and/or the cochlea simply do not form correctly...........
References


ORIENTATION TO CLASS AND CLINIC

Lab Observations

There are 5 required observations. You can do them in any order you wish. On the syllabus is a list of due dates for the observations. Observation 1 is due on the 18th of September, meaning that you must turn in one observation by the 18th. It doesn’t matter which one.

You can schedule observations on the sign up sheet located on the wall opposite Rm. 133. Once you sign up you are committed to be there for at least 40 minutes.

Rules for signing up:
- If you cannot be there at the time you signed up, then cancel your observation two days before your observation time. This will give others a chance to fill your spot.
- If you fail to attend your scheduled observation, a 1 point penalty will be assessed against your total grade.

Schedule book: The audiology schedule book is located at the reception desk. Look at the schedule book before signing up, so that you can get the type of observations needed.
- For pediatric hours, look at the birthdate of the patient. Another indication of age is the exam type: High risk screenings refer to infants.
- For adult hours, look at the birthdate next to the patients name.
- To observe a hearing aid patient, the schedule book will have an H.A. under test type.

Recording Observation Hours: In your syllabus you will find several sheets of paper labeled “OBSERVATION #.” Take one sheet every time you go to an observation. At the end of the observation, you must have Karen Bartholomew initial the sheet. This is what you will turn in to get credit for your observation.

Lab Assignments

Assignments 1 and 2 can be done any place quiet. You can check out a portable audiometer in room 136 TLRB during regular office hours. You can keep them overnight, but please return the audiometers first thing the next morning.

Assignments 3, 4, and 5 require the use of immittance equipment which cannot be checked out. These assignments have to be done in the TLRB using the immittance equipment in room 122 or 116. To use the equipment, sign-up on the sheet posted outside Rm. 122. The immittance equipment in room 116 should only be used when 122 is unavailable.

Each lab assignment will be discussed in detail during the lab demonstrations.
DEMONSTRATIONS #1

Puretone Testing: Air Conduction

Review the controls on the audiometer

Lab assignment #1
   Subjects: 3 adults
   Equipment: 1 portable audiometer, 3 audiograms

Method:
   Face the person away from you
   Be in a quiet environment
   Instructions to the subject- "You will hear a tone in your (left/right) ear. When you think you hear the tone, momentarily press the button (raise a hand). If you are not sure you may take a guess and press the button anyway. Are there any questions?"
   Place the headphones directly over the meatus
   Make sure the red earphone is over the right ear and the blue earphone is over the left ear.
   Use the testing procedures on the following page.
PURE TONE THRESHOLD AUDIOMETRIC PROCEDURES


Instructions:
1. Orient client to the task
2. Specify the response mode
   a. raise and lower hand
   b. raise and lower finger
   c. say "yes"
   d. push and release a response button

Threshold method:
1. Test better ear first. If better ear is unknown, than start with the right ear.
2. Present tone at 30 dB HL.
   a. No response, present tone at 50 dB HL and successive increments of 10 dB HL until a response is obtained.
   b. Response at 30 dB HL, then go down 10 dB.
3. Present the tone again.
   a. no response, then go up 5 dB
   b. response, then go down 10 dB
4. Repeat sequence in #3 until patient responds 3 out of 5 times at a single level.

Frequencies tested:
1. 1000, 2000, 3000, 4000, 8000, 1000 (again), 500, & 250 Hz
2. Mid-octaves are 1500, 3000, 6000, & 750 Hz.

Audiogram and symbols:
Attached audiograms contain the proper dimensions and information.

Bone conduction procedures:
Instructions are the same as air conduction procedures

Frequencies tested:
1. 1000, 2000, 4000, 500, & 250 Hz.
2. Mid-octaves are 1500, 3000, & 750 if performed for air conduction.
ADAPTATION FOR PEDIATRICS

Instructions:
1. Orient client to the task - simplify language
2. Specify the response mode
   a. localization to speakers
   b. play audiometry - dropping blocks, stacking rings, etc.
   c. raise and lower hand, finger, arm
   d. say "beep", touch earphone, etc.

Earphones vs. Soundfield
   Earphones are preferred, however, if the child does not tolerate them, switch to soundfield using warble tones.

Threshold method
1. Same procedure as adult, use social reinforcers, and/or praise.
2. Accept 2 valid responses and quickly move to another frequency.

Frequencies tested
1. Use a bracketing procedure
   a. 2000, 500 Hz then switch ears and repeat.
   b. fill in other frequencies as the child's attention span permits.
2. Mid-octaves as child's attention span and hearing permits.
Case History
I. The case history is an integral part of each audiological evaluation.
   A. The final diagnosis usually takes the history into consideration.
II. Direct, highly specific, and briefly stated questions are the most effective means of history taking.
   A. Get the maximum amount of information in the minimum amount of time.
III. General history taking questions include:
    A. Reason for referral or visit
       1. Functional hearing loss
       2. Conductive
       3. Sensorineural
    B. Better ear
       1. Which ear do they use on the telephone
       2. Test the better ear first
    C. Onset of hearing loss
    D. Gradual or sudden loss
       1. Significant impact on etiology
       2. Dictates the type of tests which are carried out
    E. Associated pain
       1. Fullness
       2. Pressure
    F. Tinnitus
       1. What kind? Roaring low pitched, or ringing high pitched?
    G. Previous diagnosis and treatment
    H. Family history of hearing loss
       1. Before age 50
    I. Dizziness and vertigo
       1. Dizziness vs. vertigo

Otologic Inspection
What to look for:
   External ear
      cerumen obstruction
      collapsing canals
   Tympanic Membrane
      cone of light
      umbo
      stapes
      annular ligament
      color of TM
      other abnormalities
DEMONSTRATIONS #3 and #4

Tympanometry and Acoustic Reflex Testing

**Lab assignment #3**

Setup equipment
- Perform otoscopic exam to rule out occluding cerumen, TM perforation, or other factors that would influence test results.
- Select a probe tip
- Instruct the patient

**Tympanometry**
- Gently place the probe into the test ear
- make sure you have a good seal
- Run an admittance tympanogram with the following parameters:
  a. starting pressure set at +200 daPa
  b. pump speed set at 600/200 daPa/s
  c. pressure range of +200 to -400 daPa
  d. probe frequency of 226 Hz
- Press stop at the conclusion
- Repeat procedure for the other ear

**Acoustic reflex testing**
- The probe should already be in the test ear
- The stimulus should be placed in the nontest ear
- Go into the acoustic reflex testing mode
- Select Contra Steady to do contralateral testing
- Perform the test at the tympanometric peak pressure
- Obtain acoustic reflexes at 500, 1000, and 2000 Hz
  - Begin tone presentations at 75 dB HL
  - Increase/decrease intensity in 5 dB steps until an acoustic reflex threshold is obtained (a change of .02 on the GSI 33) or until you reach 105 dB HL
- If the thresholds are between 100-105 dB HL, they are considered elevated, report a no response if a threshold is not obtained by 105 dB HL. **DO NOT TEST ANYONE ABOVE 105 dB HL!!**
- Repeat the procedure for the opposite ear

**Summary**
- Print the results
- Clear the tests
- Tape the results on an 8 1/2” x 11” paper

Obtain pure tone thresholds (air- and bone-conduction) with proper masking.
TYMPANOGRAMS – Jerger’s Classification System

Type A

Type B

Type As

Type C

Type Ad

TM Perforation

EXTERNAL EAR CANAL VOLUME GREATER THAN 2.5 cm
DEMONSTRATION #5

Bone conduction audiometry

Method:
Placement of the bone vibrator (forehead or mastoid).
   The portable audiometers are calibrated for mastoid placement.
   The clinic audiometers are calibrated for forehead placement.
Technique for obtaining thresholds.
   Use the same procedures as the air-conduction thresholds.
Frequencies tested:
   1. 1000, 2000, 4000, 500, 250
   2. Mid-octaves are 1500, 3000, 750 if performed for air conduction

Recording results:
   Use proper audiometric symbols
DEMONSTRATION #6

Masking air- and bone-conduction

Rule for air-conduction masking
   Mask the nontest ear during air conduction testing whenever the air conduction threshold in the test ear is 40 dB more than the air or bone conduction threshold, at the same test frequency, in the nontest ear.

Rule for bone-conduction masking
   Mask the nontest ear during bone conduction testing whenever there is an air-bone gap of 10 dB or more in the test ear.

Lab assignment #2

Subjects:  3 adults (either hearing impaired, or wearing an ear plug in one ear)
Equipment:  Portable audiometer, 3 audiograms
Type of stimuli:  Puretones at the desired frequencies and masking noise (narrow band noise centered at the test frequency).
Method:
   1) First find the voluntary unmasked threshold in the test ear (TE) and nontest ear (NTE).
   2) Determine whether masking of the nontest ear (NTE) is necessary by applying the above rules for when to mask.
   3) When masking is indicated, the initial masking level in the NTE should be 15 dB greater than the air conduction threshold in the NTE. Inform the subject that they will be hearing some noise and that they should try to ignore the noise and simply listen for the tones. Masking noise is always administered via standard earphones or insert earphones (to increase interaural attenuation and thus reduce the risk of overmasking). Masking noise is never administered via a bone vibrator.
   4) Re-establish threshold in the TE with this initial amount of masking in the NTE.
   5) Each time the patient responds to the puretone signal presented to the TE, increase the masking level presented to the NTE by 5 dB.
   6) Each time the patient does not respond to the tone presented to the TE, increase the signal level in 5 dB steps until the patient again responds.
   7) Continue the procedure until the masking can be increased four consecutive 5 dB steps without producing a shift in the threshold level of the TE. When this is accomplished, a “plateau” in threshold response has been reached.
   8) At this point, record both the masked threshold (on the audiogram) and the final masking level.
LAB DEMONSTRATION #7

Speech recognition threshold testing

5 dB DESCENDING METHOD

EX: 1

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<th>dB</th>
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SRT = Starting Level - # Correct + 2

2 dB DESCENDING METHOD

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</table>

SRT = Starting Level - # Correct + 1
### EX: 2

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<tr>
<th>dB</th>
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SRT = Starting Level - # Correct + 2

### EX: 2

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<th>dB</th>
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</tbody>
</table>

SRT = Starting Level - # Correct + 1
SPEECH RECOGNITION THRESHOLD TESTING PROCEDURES

Descending Method
1. Familiarize the subject with the word list.
2. Begin the testing at 25 dB above either:
   a) PTA of 500, 1000 and 2000
   b) Best two frequency average of 500, 1000 or 2000.
   c) or if does not respond to ‘a’ or ‘b’ above determine a ‘comfortable level’ and begin at that level (without adding the 25 dB).
3. Decrease in 10 dB steps until the subject’s threshold is approached (usually indicated by making a mistake in repeating the word(s)).
4. The intensity would then decrease in 5 dB steps and increase in 10 dB steps until the subject scores 50%, or 3 out of 5 presentations (or 2 out of 3).

Ascending Method
1. Familiarize the subject with the word list.
2. Begin at 0 dBHL (some recommend at the lowest audiometer setting, but not necessary).
3. Increase in 10 dB steps until the first response is heard from the subject.
4. Decrease 15 dB below the level just identified.
5. Increase in 5 dB increments until a correct response is obtained.
6. Decrease 15 dB below the level just identified.
7. Repeat steps 5 and 6 until the subject scores 50%, or 3 out of 5 presentations (or 2 out of 3 if the patient’s responses are consistent and reliable).

ASHA Guidelines for Determining Threshold Level for Speech (2 dB Method)
1. Familiarize the subject with the word list.
2. Begin the testing at 25 dB above either:
   a) PTA of 500, 1000 and 2000
   b) Best two frequency average of 500, 1000 or 2000.
   c) or if does not respond to ‘a’ or ‘b’ above determine a ‘comfortable level’ and begin at that level (without adding the 25 dB).
3. Present one word to the subject.
   a) If the subject does NOT respond increase the intensity by 20 dB until the subject responds (presenting one word at each increment).
   b) If the subject DOES respond then decrease the intensity by 10 dB steps presenting one word at each decrement until the subject MISSES the word.
   c) Present a second word at the level just established where the subject missed the word.
   d. Continue the process of decreasing in 10 dB steps until 2 consecutive words are missed at the same level. Your starting point is 10 dB above this level (set the audiometer to this level; e.g., 10 dB above the two consecutive misses).
4. Present two words at the starting level and decrease by 2 dB steps.

---

5 The Ascending Method takes a bit longer and the subject may experience more difficulty than the Descending Method or ASHA’s recommend method.
a) If 5 out of the first 6 words are CORRECT then continue.
b) If the above criteria is not met begin again using a starting level 10 dB above the previous starting level and repeat this process until the subject meets the criteria (i.e., 5 correct responses out of the first six word presentations).

5. As you continue presenting two words at each 2 dB decrement the test is completed when the subject MISSES five of the last six words presented.

6. Threshold is then calculated by subtracting the total number of correct from the starting level and thence adding one⁶ to that value. For example:

<table>
<thead>
<tr>
<th>Starting level (dB HL) 60</th>
<th>+ (1)</th>
<th>+ (2)</th>
<th>Starting level established according to 3 above</th>
</tr>
</thead>
<tbody>
<tr>
<td>dB HL 58</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>dB HL 56</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>dB HL 54</td>
<td>+</td>
<td></td>
<td>Criteria met with 5 out of 6 correct responses</td>
</tr>
<tr>
<td>dB HL 52</td>
<td>-</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>dB HL 50</td>
<td>-</td>
<td>+</td>
<td>Eight correct responses since the starting level</td>
</tr>
<tr>
<td>dB HL 48</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>dB HL 46</td>
<td>-</td>
<td>-</td>
<td>End of test (five missed out of the last 6 words presented)</td>
</tr>
<tr>
<td>dB HL 44</td>
<td>-</td>
<td>-</td>
<td>May or may not be tested (sometimes good to confirm the previous results)</td>
</tr>
<tr>
<td>dB HL 42</td>
<td>-</td>
<td>-</td>
<td>Not tested</td>
</tr>
</tbody>
</table>

Note: The numbers in ‘( )’ indicates the cumulative number of correct responses from the starting point.

ASHA Guidelines for Determining Threshold Level for Speech (5 dB Method)⁷
1. Familiarize the subject with the word list.
2. Begin the testing at 25 dB above either:
   a) PTA of 500, 1000 and 2000
   b) Best two frequency average of 500, 1000 or 2000.

⁶ This is considered a correction factor which is one for 2 dB decrements and two for 5 dB decrements).
⁷ Italics represent differences between the 2 dB method and the 5 dB method.
c) or if does not respond to ‘a’ or ‘b’ above determine a ‘comfortable level’ and begin at that level (without adding the 25 dB).

3. Present one word to the subject.
   a) If the subject does NOT respond increase the intensity by 20 dB until the subject responds (presenting one word at each increment).
   b) If the subject DOES respond then decrease the intensity by 10 dB steps presenting one word at each decrement until the subject MISSES the word.
   c) Present a second word at the level just established where the subject missed the word.
   d. Continue the process of decreasing in 10 dB steps until 2 consecutive words are missed at the same level. Your starting point is 10 dB above this level (set the audiometer to this level; e.g., 10 dB above the two consecutive misses).

4. Present five words at the starting level and decrease by 5 dB steps.
   a) If 4 out of the first 5 words are CORRECT then continue.
   b) If the above criteria is not met begin again using a starting level 10 dB above the previous starting level and repeat this process until the subject meets the criteria (i.e., 5 correct responses).

5. As you continue presenting five words at each 5 dB decrement the test is completed when the subject MISSES all words in the series.

6. Threshold is then calculated by subtracting the total number of correct from the starting level and thence adding two to that value. For example:

   Starting level = 60 dBHL
   Number correct= 8
   Correction Factor =2
   SRT= (60-8)+2 = 54 dBHL

A typical worksheet may look like this:

<table>
<thead>
<tr>
<th>Starting level (dB HL)</th>
<th>60</th>
<th>+</th>
<th>+</th>
<th>+</th>
<th>+</th>
<th>+</th>
<th>Starting level</th>
</tr>
</thead>
<tbody>
<tr>
<td>dB HL 55</td>
<td></td>
<td>(1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dB HL 50</td>
<td></td>
<td></td>
<td>(6)</td>
<td></td>
<td></td>
<td>(7)</td>
<td>(8)</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>End of test (5 misses at the level)</td>
</tr>
</tbody>
</table>

Note: The numbers in ‘( )’ indicates the cumulative number of correct responses from the starting point.
WORD DISCRIMINATION TESTING PROCEDURES

Test Material:  Monosyllabic words  (Isophonemic, CID W-22)

Response Mode:  Ask the patient to repeat the words they are presented with.

Recorded vs. Monitored Live Voice Presentation:  Recorded procedure is the preferred procedure, but either can be used to obtain discrimination scores. If the test is given by live voice the examiner must monitor their voice so that each word is spoken with equal effort.

Presentation Level:  35 to 40 dB SL re:SRT. If this level is too loud due to the severity of the person's hearing loss the words should be presented at their MCL.

Instruction:  Orient the patient to the task, specify response mode, indicate the type of material to be used.

Example: “You are going to hear a list of words. Each word is one syllable. I would like you to repeat the words that you hear. If you are unsure of a word, take your best guess. If you don’t have a guess than be silent and wait for the next word. Do you have any questions?”

Procedure:
1. Switch input selector to tape A and turn on the calibration tone, adjust tape A volume control so that the needle on the VU meter peaks at zero.
2. Adjust output attenuator so the output is set at the proper level (i.e. 35 dB above SL).
3. Present the word list.

Scoring:
Each word consists of three phonemes. During the test, make note of each phoneme missed. At the end of the test, you can go back and score it. Each phoneme is worth a different amount depending on the speech material used:

Isophonemic words:  Each phoneme is worth 3.3%
Monosyllabic words:  50 word list, each word is worth 2%
25 word list, each word is worth 4%.

Interpretation:
1) Most normals will reach 100% by 25 dB SL.
2) All normals will reach 100% by 40 dB SL.
3) Sensorineural hearing impairment - won't achieve 100%.
4) Retrocochlear pathology - rollover will occur.
REVIEW QUESTIONS

1. Discuss what is the study of audiology.
2. What is the contribution of the Pinna to hearing?
3. Discuss the lever action of the middle ear (i.e. ossicles) and how it moves at different sound intensities.
4. Draw and label the major anatomical landmarks of the outer, middle and inner ear.
5. Draw and label the central auditory pathway from the eighth nerve leaving the cochlea through the brainstem to the central auditory cortex.
6. List and BRIEFLY discuss the major disorders of the auditory system.
7. What is an auditory evoked potential and what is its contribution to audiology?
8. What are the non-auditory pathologies (i.e. medical conditions that affect the auditory system secondary) affecting the auditory system. BRIEFLY discuss (one or two sentences only).
9. What is P.L. 94-142 and how does it apply to the field of audiology?
10. What is the study of psychoacoustics and how does it relate to the field of audiology.
11. In detail, describe the three classical methods of psychophysics and how they are used in audiology (this is a difficult question that requires you to read the entire chapter before attempting an answer since the three methods vary in their usage in audiology)
12. Discuss the three psychoacoustic methods: 1) adaptive methods; 2) scaling procedures [FYI S.S. Stevens was LDS]; and 3) matching methods.
13. Discuss the concept of hearing threshold and how it was derived.
14. Summarizes the concept of masking and include in your discussion special situation of narrowband masking.
15. In detail, discuss what loudness and it relationship to intensity and frequency.
16. Discuss the ability of the ear in frequency and intensity discrimination.
17. What is the advantage in frequency and intensity discrimination and the effect of threshold of hearing in binaural hearing?
18. What are the primary cues for sound localization.
19. BRIEFLY describe masking level difference.
20. What is the purpose of calibrating audiometric test equipment?
21. Explain a listening check. How frequently should this be done.
22. What is a 6cc coupler used for in calibration?
23. What is required for calibration errors less than 15 dB?
24. What is required for calibration errors greater than 15 dB at any one frequency, or 10 dB at any two frequencies or more?
25. What is an artificial mastoid used for in audiometric calibration?
26. Compare and contrast the threshold of audibility and audiometric threshold (do not spend time on detailing the procedures, describe the differences and what the two are measuring and how they are used).

27. This is a question that requires DETAIL. Describe, in detail, the procedure for completing manual audiometric threshold testing. Discuss the variables that may affect the determination of audiometric threshold.

28. How does one determine the PTA and what does it mean?

29. What is 'automatic' audiometry and is the type commonly used in audiology?

30. What is meant by clinical masking and why is it necessary?

31. Discuss the variable affecting masking?

32. What is meant by the occlusion effect and how does that relate to masking?

33. Explain the concept of effective masking.

34. What type of masking is preferred for pure tone audiometry and why is it preferred?

35. What are the major considerations when determining when to mask?

36. DETAIL the recommended masking procedure for air conduction (this is an extensive answer). For: 1) air conduction; 2) bone conduction and 3) speech audiometry.

37. What is the effect of overmasking? How can one determine if overmasking has occurred.

38. What is the effect of undermasking? How can one determine if undermasking has occurred.

39. What is the advantage in using an insert receiver in audiommetric testing?

40. What is the contribution of immittance measurements to masking problems? Why might doing this procedure FIRST be of benefit to the clinician?

41. When sound is applied to the skull how is it distributed across the skull?

42. What is meant by interaural attenuation and what are the values for air-conduction and bone-conduction?

43. What is the effect of the placement of the vibrator on various locations on the skull?

44. Define the following: SRT, SAT, SDT and ST.

45. What is the definition of speech reception threshold, how is it determined and what stimulus is used to determine the speech reception threshold?

46. What is a performance-intensity function?

47. Explain, in DETAIL, the ASHA recommended method for determining SRT.

48. What is meant by a spondee word list?

49. What is a PB word and how does it differ from a Spondee word?

50. Compare and contrast the various word lists used in audiology, specifically PAL PB-50 Word Lists, CID W-22 Word Lists, NU-4 and NU-6 Word Lists, Rhyme Tests, and the CCT.

51. What is meant by a CNC word?

52. Discuss the following and how each of these variable may affect speech discrimination scores: 1) Presentation level; 2) signal to noise ratio or competing noise; 3) work familiarity; 4) closed vs open set response; 5) response mode; 6) half- vs full- list presentation; 7) the use of a carrier phrase; 8) recorded vs MLV; and 9) instruction to the subject.
53. What is meant by a central auditory disorder and how does that differ from a peripheral hearing loss?
54. What type of test material is most commonly used in assessing central auditory disorders?
55. Explain the principles of acoustic immittance measurements (i.e. how it works). Be sure to include a schematic in your discussion.
56. Discuss the principles of tympanometry and how it relates to movement of the tympanic membrane.
57. Discuss the principles used in Eustachian tube function.
58. Discuss the principles used in acoustic reflex testing.
59. What is the primary use of tympanometry (i.e. what does it measure)?
60. What is the primary use of static acoustic immittance?
61. Draw a tympanogram that would be typical of a normal middle ear.
62. Draw a tympanogram that would be typical with serous otitis media.
63. Draw a tympanogram that would indicated some type of transient middle ear problem (i.e. the beginning or ending of middle ear effusion).
64. What characteristics of a normal tympanogram differ in adults vs infants?
65. Draw and discuss the neural pathway of the acoustic reflex.
66. In using the acoustic reflex measure how would one test for recruitment?
67. What is acoustic reflex decay, how is it used and what is normal vs abnormal (use a schematic drawing)?
68. In taking a case history in pediatrics, what are the high risk factors developed by the joint committee of the AAP, AAOO, and ASHA?
69. What is the estimated prevalence of hearing loss in the newborn period?
70. In school age children approximate what percentage of middle ear hearing loss go undetected?
71. What is the purpose of a hearing screening program?
72. Discuss the advantages and disadvantages of group vs individual hearing screenings.
73. What is the referral criteria for hearing testing and/or for medical intervention?
74. What role does immittance audiometry play in a screening program?
75. Describe the development response to sound from birth to five years of age.
76. Describe the development of language from birth to five years of age.
77. What is meant by localization?
78. What is TROCA and how is it used?
79. BRIEFLY describe BOA, VRA, TROCA.
80. How might the acoustic reflex be used in trying to assess hearing sensitivity in infant and children?
81. How might auditory brainstem evoked potentials be used to assess hearing sensitivity in infants and children? What is the major limitation of this procedure?
82. In the newborn period what pre- and neo- natal factors would place an infant at risk for hearing loss?
83. What considerations must be addressed in using speech material to test young children?
84. What is an auditory perceptual disorder?
85. What characterizes an auditory perceptual disorder?
86. What is meant by binaural fusion?
87. What is meant by a developmental disorder of the auditory system and how or to what extent are other systems involved?
88. What is presbycusis, what effect does it have on the auditory system and how can one recognize it from an informal speech sample?
89. What does OSHA stand for?
90. Define TTS.
91. Define PTS.
92. What is the maximum continuous noise level in dBA that a worker may be exposed to before exceeding federal guidelines and hearing protection required?
93. What are the basic components of an industrial hearing conservation program?
94. What is pseudohypacusis?
95. Compare and contrast pseudohypacusis in adults and children.
96. What is a 'shadow' curve?
97. In comparing the SRT and PTA when would one suspect pseudohypacusis?
98. What is the Lombard test?
99. What happens in a delayed feedback test?
100. What psychoacoustic phenomenon is the Stenger test patterned after?
101. Describe the effects of hearing loss on language development in children.
102. What are the effects of hearing loss on reading and writing?
103. What is the effect of hearing loss on the development of social skills?
104. What is the effect of hearing loss on expressive language?
105. What is PL 94-142 and the impact of this law on the education of the hearing impaired?
106. Design and BRIEFLY describe an educational audiology program. Include frequency of screening.
107. Discuss body type hearing aids, BTE and ITE hearing aids. Include in your discussion the physical differences and how and under what condition each of these would be used.
108. What is peak clipping?
109. What is amplitude compression?
110. Discuss monaural vs binaural fitting of hearing aids and under what conditions each would be used.
111. Discuss the four general degrees of hearing loss and the type of amplification, the prognosis for amplification use and what might be expected to be gained from the amplification.
112. In hearing aid orientation what are the key factors in successful hearing use?
113. What should be the principle components of a parent-infant program (outline and describe in detail).
114. Outline the basic principles in the following auditory training program: 1) the Carhart program; 2) the Hirsh-Erber-Ling Program; 3) the verbotonal program; and 4) an auditory/language patterning program.

115. What is the value of hearing aid orientation and how effective is such training?

116. What are the major needs of the geriatric client and what special considerations must be undertaken in hearing aid selection and orientation (i.e. auditory training)?

117. Define the following: SPL, HL, SL, LDL, UCL, MCL, SRT, WDS

118. What is an air-bone gap?

119. What is the purpose of AGC on a hearing aid?

120. How should an earmold be cleaned?

121. What is meant by attenuation?

122. What is auditory closure?

123. When is a baseline audiogram used?

124. What is meant by cochlear reserve?

125. What type of auditory problems might accompany cleft lip?

126. Discuss the differences between SPL and HL and how the two are related and derived.

127. What is an equal loudness contour?

128. What is the measure of loudness?

129. What are the differences between frequency, intensity, pitch and loudness. How are each of these measured?

130. Draw and label the complete auditory system. The detail should emphasize those anatomical sites important to hearing.

131. What does tonotopic organization mean, and how and where is it represented in the auditory system?

132. Describe both morphologically and functionally the difference between the two sets of hair cells
ACOUSTIC REFLEX HANDOUTS
Includes Acoustic Reflex Arc and Case Studies

NEURAL PATHWAY OF THE ACOUSTIC REFLEX (STAPEDIUS MUSCLE)
Case Study #1: SUMMARY
RE Cochlear Lesion

RE Ipsi and LE Contra ARTs are elevated, absent or reduced. LE Ipsi and RE Contra ARTs are normal.

Case Study #2: SUMMARY
RE Retrocochlear Lesion

Summary: RE Ipsi and LE Contra ARTs are elevated or absent. LE Ipsi and RE Contra ARTs are normal.
Case Study #3: SUMMARY
LE Facial Nerve Lesion

Summary: RE Ipsi and Contra ARTs are normal. LE Ipsi and Contra ARTs are elevated or absent.

Case Study #4: SUMMARY
Left Middle Ear Lesion

Summary: RE Ipsi ARTs are normal. RE Contra, LE Ipsi, and LE Contra ARTs are elevated or absent.
GUIDELINES FOR SCREENING AND AUDIOLOGICAL ASSESSMENT

Supplemental Readings

Joint Committee on Infant Hearing 1990
Position Statement

The following expanded position statement was developed by the Joint Committee on Infant Hearing and approved by the American Speech-Language-Hearing Association (ASHA) Legislative Council (LC 40-90) in November 1990. Joint Committee member organizations that approved this position statement and their respective representatives who prepared this statement include the following: American Speech-Language-Hearing Association - Fred H. Bess, chair, Noel D. Matkin and Evelyn Cherow, ex officio; American Academy of Otolaryngology-Head and Neck Surgery – Kenneth M. Grundfast, co-chair; American Academy of Pediatrics – Allen Erenberg and William P. Potsic; Council on Education of the Deaf (A.G. Bell Association for the Deaf, American College of Educators of the Hearing Impaired, Convention of American Instructors of the Deaf, and the Conference of Educational Administrators Serving the Deaf) - Lita Aldridge and Barbara Bodner-Johnson; Directors of Speech and Hearing Programs in State Health and Welfare Agencies - Thomas Mahoney. Consultants: Alan Salesy and Gregory J. Matz. Ann L. Carey, 1988-1990 vice president for professional and governmental affairs, was the ASHA monitoring vice president.

II. Identification

The risk factors that identify those neonates who are at-risk for sensorineural hearing impairment include the following:

1. Family history of congenital or delayed onset childhood sensorineural impairment.
2. Congenital infection known or suspected to be associated with sensorineural hearing impairment such as toxoplasmosis, syphilis, rubella, cytomegalovirus and herpes.
3. Craniofacial anomalies including morphologic abnormalities of the pinna and ear canal, absent philtrum, low hairline, etcetera.
4. Birth weight less than 1500 grams (~3.3 lbs.).
5. Hyperbilirubinemia at a level exceeding indication for exchange transfusion.
6. Ototoxic medications including but not limited to the aminoglycosides used for more than 5 days (e.g., gentamicin, tobramycin, kanamycin, streptomycin) and loop diuretics used in combination with aminoglycosides.

Recent research and new legislation (P.L. 99-457) suggest the need for expansion and clarification of the 1982 criteria. This 1991 statement expands the risk criteria and makes recommendations for the identification and management of hearing-impaired neonates and infants. The Joint Committee recognizes that the performance characteristics of these new risk factors are not presently known; further study and critical evaluation of the risk criteria are therefore encouraged. The protocols recommended by the Committee are considered optimal and are based on both clinical experience and current research findings. The Committee recognizes, however, that the recommended protocols may not be appropriate for all institutions and that modifications in screening approaches will be necessary to accommodate the specific needs of a given facility. Such factors as cost and availability of equipment, personnel and follow-up services are important considerations in the development of a screening program (Turner, 1990).

II. Identification

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6. Ototoxic medications including but not limited to the aminoglycosides used for more than 5 days (e.g., gentamicin, tobramycin, kanamycin, streptomycin) and loop diuretics used in combination with aminoglycosides.
III. Audiologic Screening

Recommendations for Neonates and Infants

A. Neonates

Neonates who manifest one or more items on the risk criteria should be screened, preferably under the supervision of an audiologist. Optimally, screening should be completed prior to discharge from the newborn nursery but no later than 3 months of age. The initial screening should include measurement of the auditory brainstem response (ABR) (ASHA, 1989). Behavioral testing of newborn infants' hearing has high false-positive and false-negative rates and is not universally recommended. Because some false-positive results can occur with ABR screening, ongoing assessment and observation of the infant's auditory behavior is recommended during the early stages of intervention. If the infant is discharged prior to screening, or if ABR screening under audiologic supervision is not available, the child ideally should be referred for ABR testing by 3 months of age but never later than 6 months of age.

The acoustic stimulus for ABR screening should contain energy in the frequency region important for speech recognition. Clicks are the most commonly used signal for eliciting the ABR and contain energy in the speech frequency region (ASHA, 1989). Pass criterion for ABR screening is a response from each ear at intensity levels 40 dB nHL or less. Transducers designed to reduce the probability of ear-canal collapse are recommended.

If consistent electrophysiological responses are detected at appropriate sound levels, then the screening process will be considered complete except in those cases where there is a probability of progressive hearing loss (e.g., family history of delayed onset, degenerative disease, meningitis, intrauterine infections or infants who had chronic lung disease, pulmonary hypertension or who received medications in doses likely to be ototoxic). If the results of an initial screening of an infant manifesting any risk criteria are equivocal, then the infant should be referred for general medical, otological, and audiological follow-up.

B. Infants

Infants who exhibit one or more items on the risk criteria should be screened as soon as possible but no later than 3 months after the child has been identified as at-risk. For infants less than 6 months of age, ABR screening (see 11 A.) is recommended. For infants older than 6 months, behavioral testing using a conditioned response or ABR testing are appropriate approaches. Infants who fail the screen should be referred for a comprehensive audiologic evaluation. This evaluation may include ABR, behavioral testing (> 6 months) and acoustic immittance measures (see ASHA, 1989 Guidelines, for recommended protocols by developmental age).
IV. Early Intervention for Hearing-Impaired Infants and Their Families

When hearing loss is identified, early intervention services should be provided, in accordance with Public Law 99-57. Early intervention services under P.L. 99-457 may commence before the completion of the evaluation and assessment if the following conditions are met: (a) parental consent is obtained, (b) an interim individualized family service plan (IFSP) is developed, and (c) the full initial evaluation process is completed within 45 days of referral.

The interim IFSP should include the following:

A. The name of the case manager who will be responsible for both implementation of the interim IFSP and coordination with other agencies and persons;

B. The early intervention services that have been determined to be needed immediately by the child and the child’s family.

These immediate early intervention services should include the following:

1. Evaluation by a physician with expertise in the management of early childhood otologic disorders.

2. Evaluation by an audiologist with expertise in the assessment of young children, to determine the type, degree, and configuration of the hearing loss, and to recommend assistive communication devices appropriate to the child’s needs (e.g., hearing aids, personal FM systems, vibrotactile aids).

3. Evaluation by a speech-language pathologist, teacher of the hearing-impaired, audiologist, or other professional with expertise in the assessment of communication skills in hearing-impaired children, to develop a program of early intervention consistent with the needs of the child and preferences of the family. Such intervention would be cognizant of and sensitive to cultural values inherent in familial deafness.

4. Family education, counseling and guidance, including home visits and parent support groups to provide families with information, child management skills and emotional support consistent with the needs of the child and family and their culture.

5. Special instruction that includes:

   a. the design and implementation of learning environments and activities that promote the child’s development and communication skills.

   b. curriculum planning that integrates and coordinates multidisciplinary personnel and resources so that intended outcomes of the IFSP are achieved; and,

   c. ongoing monitoring of the child’s hearing status and amplification needs and development of auditory skills.

V. Future Considerations for Risk Criteria

Because of the dynamic changes occurring in neonatal-prenatal medicine, the committee recognizes that forthcoming research may result in the need for revision of the 1990 risk register. For example, the committee has concerns about the possible ototoxic effects on the fetus from maternal drug abuse; however, present data are insufficient to determine whether the fetus or neonate are at risk for hearing loss. In addition, yet-to-be-developed medications may have ototoxic effects on neonates and infants. Therefore, the committee advises clinicians to keep apprised of published reports demonstrating correlations between maternal drug abuse and ototoxicity and between future antimicrobial agents and ototoxicity. Clinicians should also take into account the possible interactive effects of multiple medications administered simultaneously. Finally, the committee recommends that the position statement be examined every 3 years for possible revision.

References


Guidelines: Audiologic Screening of Newborn Infants
Who Are At Risk for Hearing Impairment

The following guidelines were developed by the
ASHA Committee on Infant Hearing and
adopted by the ASHA Legislative Council in
November 1988 (LC 28-88). Current and past
members of the committee responsible for the
development of the guidelines include Deborah
Hayes (chair, 1988); Michael Sabo (chair, 1985-
87); Fred Bess; Dianne Brackett; Frank Burns;
Evelyn Cherow, ex officio; Brad Friedrich;
Judith Gravel; Jack Kile; Marcia Kushner Diane
Meyer Gary Thompson; James Thelin; and Ann
Carey, ASHA vice president for professional and
governmental affairs (1988-90) and Nancy
Becker, vice president for professional and
governmental affairs (1985-87).

Background
A Committee on Infant Hearing was
established in 1984 by the Legislative
Council (LC 27-84). The charge to that
committee: To gather and synthesize
information and policies generated by
committees and Boards of ASHA which
pertain to specie! aspects of hearing
impairment in infants, models of service
delivery to infants, and identification,
diagnosis, and management of hearing
disorders in infants; to identify and make
recommendations on research needs
regarding the development of auditory
function and dysfunction in infants,
prevention of hearing impairment in
infants, and the identification, diagnosis,
and management of hearing disorders in infants; to provide audiologic
consultation to the Joint Committee on
Infant Hearing on matters pertinent to
prevention, identification, diagnosis, and
management of infant hearing. The
initial activity of the committee was to
determine procedures that, at the present
time, are most appropriate for audiologic
screening of infants at risk for hearing
impairment. After consideration of the
many issues related to infant hearing, the
committee concluded that (a) all
newborn infants who are at risk for
hearing impairment should be identified,
b) infants identified at risk should
receive audiologic screening by auditory
evoked potentials prior to hospital
discharge, and (c) those infants who fail
initial audiologic screening or who fail
to be screened should enter an
audiologic evaluation, follow-up, and
management system.

The purpose of this report is to set forth
guidelines for the establishment of
auditory screening programs for
newborn infants who are at risk for
hearing impairment.

Guidelines for audiometric evaluation,
follow-up, and management of hearing-
impaired infants will be considered in
forthcoming activities of the Committee
on Infant Hearing.

Definitions
Infants at risk: Infants who fall into one
or more of the seven risk criteria
identified in the 1982 position statement
of the Joint Committee on Infant
Hearing (1982) are considered at risk for
hearing impairment and should receive
audiologic screening. The factors are:
1. A family history of childhood hearing
impairment.
2. Congenital perinatal infection (e.g.,
cytomegalovirus (CMV), rubella,
herpes, toxoplasmosis, syphilis).
3. Anatomic malfunction involving the
head or neck (e.g., dysmorphic
appearance including syndromal and
nonsyndromal abnormalities, overt or
submucous cleft palate, morphologic
abnormalities of the pinna).
4. Birthweight less than 1500 grams.
5. Hyperbilirubinemia at level exceeding indications for exchange transfusion.
6. Bacterial meningitis, especially H. influenza. 7. Severe asphyxia which may include infants with Apgar scores of 0-3 who fail to institute spontaneous respiration by 10 minutes and those with hypotonia persisting to two hours of age (Joint Committee on Infant Hearing, 1982). For a more complete review of these risk criteria and their relation to hearing impairment, see Gerkin (1984).

Hearing impairment: Bilateral conductive and/or sensorineural deficit in the frequency region important for speech recognition (approximately 1000 through 4000 Hz). Hearing impairment is defined as deficit in auditory sensitivity that interferes with speech recognition and for which intervention strategies are known and available.

The impact of childhood hearing impairment on speech and language development and academic achievement is well documented (Allen, 1986; Osberger, 1986). In general, hearing-impaired children demonstrate limited speech production skills (Osberger, Robbins, Lybolt, Kent, & Peters, 1986), significantly delayed receptive and expressive language skills (Moeller, Osberger, & Eccarius, 1986; Osberger, Moeller, Eccarius, Robbins, & Johnson, 1986), and reduced academic achievement, especially in language-related areas (Allen, 1986). To minimize these debilitating effects, professionals have urged early identification and habilitation of infants with hearing impairment. Efforts in both the public and private sector have been undertaken to develop screening, diagnostic, and habilitation programs to meet these goals.

In the public sector, Public Law 99-457, the Education of the Handicapped Amendment of 1986, created (in part) a new discretionary program to address the special needs of handicapped infants and toddlers from birth through 2 years of age and their families. By 1990-91, each state that wants to continue receiving federal financial assistance under the birth through-2 program must have in place a policy to provide early intervention services to all handicapped infants and toddlers. Some components of this program include development of a Child Find system, referral to service providers, research and demonstration projects, and a comprehensive system of personnel development. Provision of services must be by qualified personnel meeting the highest state standards established for employment in each profession or discipline.

In the private sector, representatives from audiology and speech-language pathology, otolaryngology, pediatrics, and nursing have participated in a Joint Committee on Infant Hearing which, over the years, has developed a series of position papers. The most recent position paper (Joint Committee on Infant Hearing, 1982) states that early detection of hearing impairment in the affected infant is important for medical treatment and subsequent educational intervention to assure development of communication skills." The Joint Committee recommended that infants at risk for hearing impairment be identified and that they receive appropriate evaluation and treatment.
Reliable data on incidence of significant hearing impairment in infants and young children are unavailable (Hotchkiss, 1987; Ries, 1986). National statistics indicate that approximately 3.7 million children are born in the United States each year (Wegman, 1987). Investigators estimate that 7 - 12% of all newborns are at risk for hearing impairment (Feinmesser & Tell, 1976; Jacobson & Morehouse, 1984; Mahoney & Eichwald, 1987). Moderate to profound hearing impairment is reported present in less than 2% to more than 4% of at-risk infants (Galambos et al., 1984; Jacobson & Morehouse, 1984; Mahoney and Eichwald, 1987; Stein, Ozdamar, Kraus, & Paton, 1983; Hosford-Dunn, Johnson, Simmons, Malachowski, & Low, 1987). Prevalence of milder degrees of hearing impairment in this population is unknown. Retrospective studies have shown that between 50 and 75% of hearing-impaired children were positive for at least one of the Joint Committee's risk criteria (Elssmann, Matkin, & Sabo, 1987; Feinmesser & Tell, 1976; Stein, Clark & Kraus, 1983).

In addition to infants who are at risk, infants with no known risk factors may have or develop hearing impairment (Feinmesser & Tell, 1976; Simmons, 1980). Prevalence of significant hearing impairment, including mild to moderate hearing impairment, for this population is not well defined. The dearth of data on the prevalence of hearing impairment in both at-risk newborns and newborns with no known risk factors demonstrates the pressing need for well controlled studies of the true impairment rate in these populations. Investigations on the prevalence of mild to moderate hearing impairment are especially needed.

**Rationale**

To prevent or reduce the debilitating effects of childhood hearing impairment, ASHA endorses an aggressive program of early identification and habilitation. Optimally, all newborn infants should receive audiologic screening to identify the majority of infants who require audiologic evaluation, follow-up, and management. At the present time, however, there are no data to indicate that newborn behavioral screening programs are sufficiently sensitive and specific (Durieux-Smith, Picton, Edwards, Goodman, & MacMurray, 1985; Feinmesser & Tell, 1976; Jacobson and Morehouse, 1984), or that evoked potential screening programs can be sufficiently low cost (Mahoney & Eichwald, 1987; Weber, 1987) to warrant mass screening. When cost-effective screening approaches are developed that are sensitive and specific, ASHA recommends evaluation of all newborn infants. In the interim, ASHA recommends audiologic screening of all infants at risk for hearing impairment.

**Program Components**

A successful program of early identification of hearing impairment in infants includes three components: (a) parent/caregiver education, (b) audiologic screening, and (c) evaluation, follow-up and management systems.

**Parent/caregiver education.** Parents/caregivers of all newborns should receive information about normal auditory and speech and language development, and should be informed of the importance of early audiologic evaluation of suspected hearing problems. They should receive information that will enhance their ability both to observe auditory and
speech and language development, and to advocate prompt referral for appropriate audiologic evaluation (Elssmann et al., 1987).

**Audiologic screening.** All newborn infants at risk for hearing impairment by Joint Committee on Infant Hearing criteria (1982) should receive audiologic screening. Screening can occur prior to hospital discharge (Durieux-Smith et al., 1985; Galambos, Hicks & Wilson, 1982; 1984; Gorga, Reiland, Beauchaine, Worthington, Jesteadt, 1987; Jacobson & Morehouse, 1984; Stein, Clark, & Kraus, 1983) or may be deferred until age 4 months (Albert), Hyde, Riko, Corbin, & Fitzhardinge, 1985; Durieux-Smith, Picton, Edwards, MacMurray & Goodman, 1987; Hyde, Riko, Corbin, Moroso, & Alberti, 1984) or even older (Mahoney & Eichwald, 1987).

Screening prior to hospital discharge ensures access to all infants who are identified at risk for hearing impairment (Downs & Sterritt, 1967, and, under appropriate test conditions, does not result in a significantly higher failure rate than deferred screening (Durieux-Smith et al., 1987). Substantial loss-to-follow-up can occur if screening is deferred (Coplan, 1987 Downs & Sterritt, 1967; Mahoney & Eichwald, 1987; Stein, Clark, & Kraus, 1983). In the absence of systematic nursery based screening programs, there are data indicating that hearing impairment is typically not identified until age 18 months and older, even for infants at risk for hearing impairment (Elssmann et al., 1987; Stein, Clark, & Kraus, 1983).

Further, if screening is deferred until the infant can be tested with operant conditioning behavioral test procedures, then the goal of identification and habilitation by age 6 months cannot be met for many at-risk infants because developmental age may lag behind chronological age for premature and compromised infants. For these reasons, ASHA recommends audiologic screening prior to hospital discharge.

Screening at-risk newborns (approximately 7-12% of the newborn population) should result in earlier identification and habilitation of approximately 50-75% of hearing-impaired infants (Elssmann et al., 1987; Jacobson & Morehouse, 1984; Mahoney & Eichwald, 1987; Stein, Clark, & Kraus, 1983). It is important to recognize, however, that the remaining 25-50% of hearing-impaired infants will not receive audiologic screening in the newborn nursery and will not, therefore, be identified by these procedures.

Audiologic screening is performed by an audiologist or under the supervision of an audiologist in accordance with current standards (Committee on Audiologic Evaluation, 1987). ASHA recommends that at-risk newborns receive audiologic screening using auditory evoked potential measures prior to discharge from the newborn nursery.

At the present time, auditory brainstem response (ABR) provides a reliable and valid estimate of peripheral auditory sensitivity in newborns (Galambos et al., 1982,1984; Gorga et al., 1987; Jacobson & Morehouse, 1984; Lary, Briassoulis, de Vries, Dubowitz, & Dubowitz, 1985; Schulman-Galambos & Galambos, 1975,1979)

In addition to technically appropriate application of the ABR test procedure, the audiologic screening includes (a)
professional interpretation of test results; (b) parent caregiver counseling; and (c) when appropriate, guidance into an evaluation, follow-up, and management system.

_Evaluation, Follow-up, and Management Systems Development_ of programs for identification of hearing impairment in infants is not justified without immediate availability of an appropriate evaluation, follow-up, and management system. Definition of a specific system is outside the scope of this document. At a minimum, the system must include diagnostic and habilitative audiologic services, and general medical and otologic services as recommended by the Joint Committee on Infant Hearing (1982). These services require involvement of an interdisciplinary team.

### Protocol for Audiologic Screening of At-Risk Newborn Infants

The recommended process for identification and audiologic screening of at-risk newborn infants is shown in Figure 1. Population

ASHA recommends that all newborn infants receive evaluation for risk status by Joint Committee on Infant Hearing (1982) criteria prior to discharge from the newborn nursery (well baby nursery for healthy newborns; intensive care nursery for ill or compromised infants). Parents should receive information about expected milestones in auditory and speech-language development and should be informed of the importance of audiologic evaluation of suspected hearing problems. Those infants who have no known risk factors do not receive audiologic screening by ABR prior to discharge. An infant who exhibits abnormal auditory behavior or delayed speech and language development or whose parent/caregiver expresses concern about auditory responsiveness should receive audiologic evaluation.

### Procedure

Infants at risk for hearing impairment should receive audiologic screening. The purpose of this screening is to identify those infants whose responses do not meet pass criteria and who therefore should enter an audiologic evaluation, follow-up, and management system.

The recommended procedure is ABR prior to discharge. If the infant is discharged prior to screening, or if ABR screening under audiologic supervision is unavailable, then the parent/caregiver should be informed of the importance of audiologic follow-up for the infant.

The infant should be referred to an audiologist for determination of appropriate evaluation, follow-up, and management strategies.

The acoustic stimulus for ABR screening should contain energy in the frequency region important for speech recognition. Clicks are the most commonly used signal for eliciting the ABR (Committee on Audiologic Evaluation, 1987) and contain energy in the speech frequency region (Gorga, Abbas, & Worthington, 1985; Jerger & Mauldin, 1978). Other signals that may be used include tone pips or tone bursts, or clicks in the presence of masking noise.
Pass Criterion

Pass criterion for ABR screening is a response from both ears at intensity levels 40 dB nHL or less. Infants whose responses meet this criterion should receive audiologic follow-up as necessary for medical evaluation and management and/or developmental evaluation. It is important that parents/caregivers and primary health care providers understand that "pass" on ABR screening does not rule out development of hearing impairment in infancy or early childhood (Nield, Schrier, Ramos, Platzker, & Warburton, 1986). Parents/caregivers and primary health care providers should remain vigilant to the infant's auditory behavior and speech and language development, and should be encouraged to advocate for audiologic evaluation if they are concerned about the infant's communication development.

Infants whose responses meet pass criterion and who are at risk for progressive hearing impairment should receive audiologic monitoring on a periodic basis and probably through the preschool years (Coplan, 1987). Factors that are known at the present time to place an infant at risk for progressive hearing impairment include family history of progressive hearing impairment (Konigsmark & Gorlin, 1976), congenital cytomegalovirus [(CMV) (Dahle, McCollister, Stagno, Reynolds, & Hoffman, 1979; Stagno et al., 1977)], and PPHN (Naulty et al., 1986; Sell et al., 1985).

Refer Criterion/Follow-Up

Infants who do not demonstrate responses at intensity levels 40 dB nHL or less in both ears should enter the audiologic evaluation, follow-up, and management system.

Infants who demonstrate responses at 40 dB nHL or less from only one ear should receive audiologic monitoring until either (a) both ears meet pass criterion or (b) stable unilateral hearing impairment is confirmed and follow-up and management is initiated. Comprehensive audiological evaluation may include additional evoked potential evaluation, behavioral testing, and acoustic immittance measures. These infants are also referred for medical evaluation specified by the Joint Committee on Infant Hearing (1982): 1. General physical examination and history including: a. Examination of the head and neck, b. Otoscopy and otomicroscopy, c. Identification of relevant physical abnormalities, d. Laboratory tests such as urinalysis and diagnostic tests for perinatal infections. Habilitation of hearing-impaired infants should be initiated by age 6 months (Joint Committee on Infant Hearing, 1982). Estimates of peripheral sensitivity based on electrophysiologic procedures should be confirmed by behavioral techniques as soon as possible. Efforts to confirm electrophysiologic estimates of peripheral sensitivity may coincide with on-going habilitation. In general, precise behavioral estimates of hearing sensitivity can be obtained when the infant can respond to operant conditioning test procedures [(approximately 5-6 months developmental age) Thompson & Wilson, 1984)]. Management decisions made prior to defining the behavioral
audiogram may require modification as more precise estimates of hearing sensitivity are obtained.

Summary

The importance of early identification of hearing impairment is well documented. The Joint Committee on Infant Hearing 1982 Position Statement established the goal of identification and habilitation of hearing-impaired infants by age 6 months but did not specify the procedure for initial audiologic screening. In these guidelines, ASHA specifies the recommended procedure for audiologic screening of infants at risk for hearing impairment that includes a) parent caregiver education; b) audiologic screening by ABR; and c) referral to a comprehensive evaluation, follow-up, and management system for those infants who fail initial ABR screening. The procedures recommended in these guidelines are complex and require substantial involvement of a qualified audiologist. Identification programs should be instituted only when all components are available to provide appropriate services to the infant and his/her family. It is hoped that these guidelines will encourage implementation of programs for early identification of hearing impairment in at-risk infants.

Hearing Tests and Measurement
ASLP 438
1/6/2006

All Newborn Infants

Joint Committee on Infant Hearing Risk Criteria

No Risk Factor

1. Parent/caregiver information and education
2. No audiologic screening unless parent/caregiver expresses concern about auditory behavior or speech and language development

At Risk

1. Parent/caregiver education
2. Audiologic screening by ABR prior to newborn nursery discharge

"Pass," but at risk for progressive hearing impairment

"Pass"

Audiologic follow-up as needed for medical or developmental consideration

"Refer"

Audiologic monitoring; management as needed

Enter Evaluation, follow-up, and management system

a. Pass = Response at 40dB nHL or less from both ears.
b. Refer = Failure to demonstrate response at 40dB nHL from either one or both ears.
Guidelines for the Audiologic Assessment of Children From Birth Through 36 Months of Age

Committee on Infant Hearing
American Speech-Language-Hearing Association

The Guidelines for the Audiologic Assessment of Children From Birth Through 36 Months of Age were developed by the American Speech-Language-Hearing Association (ASHA) Committee on Infant Hearing and adopted by the ASHA Legislative Council (LC 20-90) in November 1990. Current and past members of the committee responsible for the development of the guidelines include Jack E. Kile, chair; Fred Bess; Evelyn Cherow, ex officio; Janet Coscarelli; Judith S. Gravel; O. T. Kenworthy; Marcia Fl. Kushner; Noel D. Matkin; James W. Thelin; and Barbara Cone Wesson. Ann L. Carey, vice president for professional and governmental affairs (198-90), was the monitoring vice president.

Scope

In accordance with the recommendations of the "Guidelines for Audiologic Screening of Newborn Infants Who Are at Risk for Hearing Impairment" (Asha, 1989), the ASHA Committee on Infant Hearing has developed "Guidelines for the Audiologic Assessment of Children from Birth Through 36 Months of Age." The committee has specifically limited the scope of this document to assessment. Guidelines relative to identification and management will be addressed in forthcoming documents from other committees of ASHA.

In developing these guidelines, the ASHA Committee on Infant Hearing recognizes the complex and multidimensional nature of hearing and its development. The committee further recognizes the growing number of infants with multiple developmental disabilities and the resulting challenge of accurately delineating their hearing status. Therefore, the committee recommends the use of multiple, nonduplicative procedures that sample various dimensions of auditory function (e.g., responses to threshold and supra-threshold stimuli). Yet the committee remains mindful of the need for cost containment in healthcare delivery (Administration on Developmental Disabilities, 1988; Kurent, 1989; U.S. General Accounting Office, 1985). Accordingly, the committee acknowledges that the type and number of procedures administered to any child should be dictated as much by the reliability and completeness of the results as by any specified assessment protocol (Turner, Frazer, & Shepard, 1984).

This document should be regarded as guidelines for practice, not standards. The committee recognizes that each individual case presents unique characteristics that may influence the approach to the evaluation. Nevertheless, the committee has provided specific procedural recommendations that are supported by research evidence and cumulative clinical experience. The committee encourages further study of these guidelines to evaluate the efficacy of the procedures and protocols recommended.

**Background**

Early and comprehensive assessment of hearing status is critical to the provision of appropriate, individualized intervention strategies for children. Pursuant to the screening guidelines (ASHA, 1989) and the Joint Committee on Infant Hearing Position Statement (1982), the present report sets forth guidelines for the audiologic evaluation of children who are either identified through screening programs or referred directly to audiologists for hearing assessment.

The mandate for developing these guidelines is derived from several sources. Public Law 90 457, a discretionary program to address the special needs of handicapped children from birth through 2 years of age, emphasizes the need for appropriate assessments and for personnel qualified to provide these procedures. Second, ASHA's Legislative Council (LC 27-84) charges the Committee on Infant Hearing to gather and synthesize policies that pertain to identification, diagnosis, and management of hearing disorders in infants. Third, research on the impact of hearing impairment on speech-language, social, and cognitive development as well as subsequent academic achievement supports the need for early identification and rehabilitation of children with hearing impairment. (See Davis, 1988, for a review).

ASHA (1989) guidelines for screening newborn infants recommend audiologic assessment for high-risk infants who fail audiologic screening by auditory brainstem response (ABR) procedures. Furthermore, those guidelines recommend that any child (regardless of risk or screening status) "who exhibits abnormal auditory behavior or delayed speech and language development, or whose parent/caregiver expresses concern about auditory responsiveness should receive audiologic evaluation" (Asha, 1989, p. 91). The underlying principle is that once a child is suspected of having hearing impairment, then a comprehensive assessment must be completed in a timely fashion in order to initiate medical referrals, aural rehabilitation, and educational management.

Behavioral assessment of hearing sensitivity in children has been complicated by developmental and maturational limitations. Thus, early behavioral assessment techniques relied on observation of reflexive responses and/or state changes in the presence of an auditory stimulus (Downs & Sterritt, 1967; Eisenberg, 1976; Friedrich, 1985; Thompson & Weber, 1974). Behavioral

Observation Audiometry (BOA) techniques, even with normal-hearing children, often are confounded by nonspecific responses to sound, false positive responses, or differential responses depending on stimulus spectrum, observer bias, and widely variable threshold values (Bench, Collyer, Mentz, & Wilson, 1976; Northern & Downs, 1984; Weber, 1969; Wilson & Thompson, 1984). Published age-related response levels for various stimuli (pure tones, white noise, speech) have been used for judging normal versus abnormal auditory responses (Northern & Downs, 1984). The validity of this approach has not been supported by research that focused on unconditioned auditory responses involving large samples of normal-hearing and hearing-impaired children.

In contrast, research by Moore, Thompson, Wilson, and their colleagues (Moore, Thompson, & Thompson, 1975; Moore, Thompson, & Wilson, 1977; Primus & Thompson, 1985; Thompson, 1985; Thompson & Folsom, 1981; 1984; Thompson & Wilson, 1984; Thompson, Wilson, & Moore, 1979; Wilson, 1978; Wilson & Thompson, 1984) has demonstrated that it is possible to elicit reliable conditioned auditory responses from children using an operant, visually reinforced behavioral response technique. Normally developing children as young as 5 months of age may be trained to produce a motor response contingent upon the presence of an auditory stimulus (Wilson & Thompson, 1984). The behavior, usually a head turn, is reinforced by an appealing visual display. These researchers, as well as others, have demonstrated that frequency-specific thresholds may be obtained from infants, allowing the accurate evaluation of hearing sensitivity regardless of type, degree, or configuration of impairment (Bernstein & Gravel, 1990; Diefendorf, 1988; Gravel, 1989; Nozza & Wilson, 1984; Wilson & Thompson, 1984).

Auditory evoked potential measurements, especially the ABR, can provide estimates of threshold sensitivity. The use of the ABR has an important role in both identification and assessment protocols, particularly with children too young or too disabled to be reliably assessed using conditioned behavioral techniques (Stein & Kraus, 1989). The ABR elicited by air-conducted clicks provides an estimate of sensitivity in high-frequency regions (Coats & Martin, 1977; Jerger & Mauldin, 1978; Yamada, Kodera, & Yagi, 1979; Yamada, Yagi, Yamane, & Suzuki, 1975). ABR tests employing frequency-specific stimuli such as tone-pips (Gorga, Worthington, Reiland, Beauchaine, & Goldgar, 1985, Hyde, 1985, Stapells, Picton, Perez-Abalo, Read, & Smith, 1985) further extend the application of ABR tests for defining the degree and configuration of hearing impairment. The use of bone-conducted stimuli (Mauldin & Jerger, 1979; Stapells & Ruben, 1989; Yang, Rupert, & Moushegian, 1987; Ysunza & Cone-Wesson, 1987) may serve to define the type of loss.

Other audiologic procedures are being developed and researched, such as electrocochleography (Sullen, Berlin, Gondra, & Adams, 1976), middle and late auditory evoked potentials (Krause, Reed, Smith, Stein, & Cartee, 1985; Kurtzberg, 1989; McRandle, Smith, & Goldstein, 1974; Mendel, Adkinson, & Harker, 1977; Mendelson & Salamy, 1981), and, most recently, otoacoustic emissions (Kemp, 1978; Kemp, Ryan, & Bray, 1990; Norton & Widen, 1990), which may also contribute to the assessment of auditory function in children. However, further research is needed to define their clinical application.

Acoustic immittance measures (tympanometry and acoustic reflex thresholds) are an integral part of the audiologic assessment of children. Both tympanometry and acoustic reflex threshold measurements contribute to the description of middle ear status. Acoustic reflex threshold determination provides additional information relevant to hearing status (Northern, 1988).

There remain undefined parameters for the examination of tympanometric configuration and acoustic reflex measurements in young infants (McMillan, Bennett, Marchant, & Shurin, 1985; Sprague, Wiley, & Goldstein, 1985). Recognition of these limitations, however, should not preclude the routine use of acoustic immittance measures in the pediatric test battery. Rather, thoughtful interpretation of test results should be made in combination with other clinical findings. In young infants, the interpretation of acoustic reflex findings may be compromised when only the 220/226 Hz probe tone is used. The use of a higher probe tone frequency (e.g., 660/678 Hz), may provide a more valid indication of middle ear status and peripheral auditory integrity for this group of children (ASHA, 1988; Bennett & Weatherby, 1982; Himelfarb, Popelka, & Shannon, 1979; Marchant, et al., 1986; Margolis, 1978; Margolis & Popelka, 1975; Weatherby & Bennett, 1980).

In summary, the committee recommends a comprehensive audiologic assessment of children from available behavioral, electrophysiologic, and acoustic immittance measures. Responses should be replicable and either there should be agreement among measures or assessment should be continued until consensus is reached. The use of any test alone for assessing children's hearing sensitivity is discouraged (Friedrich, 1985; Gravel, Kurtzberg, Stapells, Vaughan, & Wallace, 1989). Corroboration of test results through case history, parent report, and observations of behavior are crucial to assess functional use of hearing. Effective diagnosis and management also includes involvement of the parent/caregiver at all stages of assessment and intervention to enable families to be active participants rather than passive recipients (Cherow, 1985; Dunst, Trivette, & Deal, 1988; Education of the Handicapped Act Amendments of 1986). Ultimately, the goal is to define precisely the type, degree, and configuration of the hearing impairment for each ear. The need for such precision should not preclude initiation of intervention, including the selection and fitting of amplification (hearing aids and FM systems) and other assistive devices.

Accordingly, ongoing assessment is viewed as an integral part of ASHA,33 (Suppl. 5), 37-43, the management process. Further, it should be recognized that single-point assessment does not adequately address the issue of progressive hearing loss. In cases where progressive hearing loss may be suspected, routine reevaluation in conjunction with otologic management is essential.

Definitions

**Assessment.** An in-depth examination of auditory function utilizing behavioral, electrophysiologic, and acoustic immittance measures to determine the degree, configuration, type, and symmetry of any auditory impairment or to determine that the child does not have hearing impairment that could impede normal communication development. Assessment facilitates medical referral/treatment, aural rehabilitation, and education planning.

**Behavioral Assessment.** An examination of hearing function using procedures in which the child provides overt, reliable responses to a variety of auditory stimuli for which the spectra and signal intensity are known. These procedures include visual reinforcement audiometry (VRA), visual or tangible reinforced operant conditioning audiometry (VROCA, TROCA), and conditioned play audiometry (CPA). All behavioral measurements of auditory sensitivity must be completed in a test environment meeting standards for background noise levels (ANSI, 1977). Signals need to be calibrated in accordance with current national standards, when applicable. When national standards do not exist, as is the case with sound field audiometry, signal calibration may be referenced to other published standards, to published data, or to values established by the clinic performing the audiologic tests. Appropriate sound field calibration is particularly critical in the behavioral audiologic assessment of children who cannot be tested under earphones. (Morgan, Dirks, & Bower, 1979; Rochlin, 1990; Walker, Dillon, & Byrne, 1984).

**Electrophysiologic Assessment.** For the purpose of these guidelines, electrophysiologic assessment refers to the measurement of evoked potentials to auditory stimuli (AEP). The most widely used AEP is the auditory brainstem response (ABR). At this time, the ABR is considered the AEP of choice for audiologic evaluation using established normative data for latency by age (ASHA, 1987). Consistent with other measurements of auditory sensitivity, all AEP measurements must be completed in a test environment meeting standards for background noise levels (ANSI S3.1-1977).

**Acoustic Immittance Assessment.** Acoustic immittance refers to the measurement of middle ear function by tympanometry and the determination of acoustic reflex thresholds using tonal stimuli and noise bands.

Hearing Impairment. Unilateral or bilateral conductive and/or sensorineural deficit in the frequency range most important for speech recognition (500-4,000 Hz). Based largely upon adult, pure-tone normative values, various classifications of hearing impairment have been published (Clark, 1981). However, research and clinical experience with children suggests that any classification of hearing loss by degree may not adequately indicate the adverse impact of hearing impairment on development (Kenworthy, Bess, Stahiman, & Lindstrom, 1988).

Target Population. The following children should be referred for audiologic evaluation:

• any child who failed a newborn hearing screening,

• any child who is suspected by a parent/primary caregiver, educator, or primary care physician of having hearing loss

• any child "who exhibits abnormal auditory behavior or delayed speech and language development," (ASHA Guidelines, 1989, p. 91).

• any child not previously screened who is identified as at high risk for hearing loss based on the Joint Committee on Infant Hearing Position Statement (1982) or any subsequent revisions (Joint Committee on Infant Hearing 1990 Position Statement, 1991, Suppl. - 5, p. 3 ).

Several guiding principles were of paramount importance in compiling the recommendations for appropriate assessment procedures. These principles include (a) individualized timely assessment protocol, (b) use of frequency-specific stimuli, (c) ear-specific assessment and (d) determination of middle ear status by bone conduction and acoustic immittance measurements.

Individualized, Timely Assessment Protocol

Children undergo rapid sensory, motor, and cognitive development. Thus, it is essential that assessment tools be chosen that are appropriate for the neurodevelopmental state of the young child. Although a thorough assessment of the hearing impairment may not be completed at one point in time, prolonged delays between assessments should be avoided. Although serial evaluations yield the best information upon which to base management decisions, the diagnosis and remediation of any existing hearing loss should not be delayed because of an inability to reliably complete any particular test.

Use of Frequency-Specific Stimuli

Acoustic stimuli used for assessment should provide frequency-specific information regarding auditory sensitivity. Therefore, responses to pure tones, FM tones, or narrow bands of noise should be obtained in behavioral testing of children regardless of the response levels obtained to broadband signals (e.g., speech, music, or environmental sound). Because high-frequency spectral energy (above 1,000 Hz) is critical to speech perception, audiologic assessment of children should always include test stimuli that allow the clinician to evaluate hearing sensitivity within the high-frequency range. The Committee suggests that at a minimum, thresholds be obtained at 500 Hz and 2,000 Hz to allow for the selection of appropriate amplification (Matkin, 1987).

Frequency-specific stimuli are also recommended for ABR assessment. The use of click stimuli alone is not sufficient for the estimation of audiometric configuration (Eggermont, 1982; Stapells, et al., 1985; Stapells, 1989). Thus, it is recommended that frequency-specific stimuli be used when comprehensive ABR testing is undertaken (Hyde, 1985; Stapells, et al., 1985; Stapells, 1989). ABR thresholds for clicks generally correlate well with pure-tone thresholds in the high-frequency range (Coats & Martin, 1977; Jerger & Mauldin, 1978; Yamada, Yagi, Yamane, & Suzuki, 1975; Yamada, Kodera, & Yagi, 1979). The ABR thresholds for low-frequency stimuli (Gorga, et al., 1985), and low-frequency stimuli in notched noise (Hyde, 1985; Picton, Ouelleke, Hamel, & Smith, 1979; Stockard, Stockard, & Coen, 1983) can be used to estimate thresholds for the low-frequency region. Derived band analysis of ABR responses may also be used for this purpose (Don & Eggermont, 1978; Don, Eggermont, & Brackmann, 1979; Parker & Thornton, 1978a, 1978b). ABR test protocols should be chosen to estimate threshold in both the high and low-frequency range.

Ear-Specific Assessment

Ear-specific assessment is the goal for both behavioral and electrophysiologic procedures because a unilateral hearing loss, even in the presence of a normal-hearing ear, may place a child at significant developmental and/or educational risk (Bess, 1982; Bess, Klee, & Culbertson, 1986; Oyler, Oyler, & Matkin, 1988). Therefore, determining hearing sensitivity for each ear is important for establishing supportive evidence for medical/surgical diagnosis and treatment, selecting appropriate amplification, establishing baseline function, and monitoring auditory status when progressive or fluctuating hearing loss is suspected. Effective masking of the non-test ear should be utilized as necessary.

Determinations of Middle Ear Status by Bone Conduction and Acoustic Impittance Measurements

When air-conduction thresholds obtained by either behavioral or electrophysiologic methods are found to be elevated, estimates of bone-conduction sensitivity should be completed. In contrast, acoustic immittance should be accomplished during each test session in order to assist in the determination of middle ear status.

Findings from acoustic immittance alone are not sufficient for middle ear assessment, but they provide valuable information when considered in conjunction with other audiologic results.

Protocols

Assessment Protocol for Children Chronologically/Developmentally Birth Through 4 Months of Age (Age Adjusted for Prematurity)

At these very young ages, or for very compromised children (severely developmentally delayed or multiply impaired), the suggested methods for the comprehensive assessment of auditory function are the ABR (using click and low-frequency stimuli) and acoustic immittance in combination with case history, parent/caregiver report, and behavioral observation of the infant's responses to a variety of auditory stimuli. The behavioral observation is intended for corroboration of parent/caregiver report of the child's auditory behavior rather than for threshold estimation.

Electrophysiologic Assessment. ABR threshold and latency-intensity function should be measured for air-conducted clicks and/or tones for each ear. At a minimum, responses to clicks and low-frequency stimuli should be obtained to provide an estimate of audiometric configuration. When air-conducted ABR is elevated, an ABR to bone-conducted stimuli should be considered when equipment, normative data, and expertise are available (Mauldin & Jerger, 1979; Stapells, 1989; Stapells & Ruben, 1989; Yang, Rupert, & Moushegian, 1987; Ysunza & Cone-Wesson, 1987).

Acoustic Impittance Assessment. Tympanograms and acoustic reflexes should be assessed for both ears. The use of a probe frequency higher than 220/226 Hz for obtaining acoustic reflexes in this age range should be considered.

Behavioral Assessment. At present, reliable procedures for the behavioral assessment of hearing in this age population are not clinically available. However, this should not preclude the clinician's consideration of behavioral methods now being researched and developed (Olsho, Koch, Halpin, & Carter, 1987).

Assessment Protocol for Children Who Are Chronologically/Developmentally 5-24 Months of Age (Age Adjusted for Prematurity)

Behavioral techniques, in combination with acoustic immittance measures, are often sufficient for the comprehensive assessment of hearing for children in this age range. ABR is recommended when the validity or adequacy of behavioral test results are limited or the neurologic integrity of the auditory pathways to the level of the brainstem is in question.

Behavioral Assessment. Visual reinforcement audiometry (VRA) should be employed to assess hearing sensitivity for speech and frequency-specific stimuli. The VRA test results should include indicators of the child's response reliability. Minimally, both high- and low-frequency signals should be used, preferably at octave frequencies from 500-4,000 Hz. Ear-specific threshold information is preferable to sound field findings. Nevertheless, it is often useful to initiate VRA in the sound field or by bone conduction because the response behavior is more easily established. Word recognition measures should be applied at suprathreshold levels as early as possible, while recognizing the child's language limitations (see Assessment Protocol for Young Children). If air conduction results are elevated, unmasked bone-conduction thresholds, at a minimum, should be obtained.

Acoustic Immittance Assessment. Tympanograms and acoustic reflex thresholds should be assessed in both ears. Additional acoustic reflex measurements using broadband noise stimuli may provide useful information about auditory status (Jerger, Gurney, Mauldin, & Crump, 1974; Jerger, Hayes, Anthony, & Mauldin, 1978; Margolis & Fox, 1977; Neimeyer & Sesterhenn, 1974; Popelka, Margolis, & Wiley, 1976; Silman & Gelfand, 1978; 1981). (See comments regarding probe-tone frequency in Assessment Protocol for Children Through 4 months of Age.)

Electrophysiologic Assessment. When behavioral findings are incomplete or inconclusive or are judged as unreliable, an ABR to air-conducted clicks and/or tones is recommended. If air-conducted ABR threshold estimates are elevated, bone-conducted measures should be considered when equipment, normative data, and expertise are available (Mauldin & Jerger, 1979; Stapells, 1989; Stapells & Ruben, 1989; Yang, Rupert, & Moushegian, 1987; Ysunza & Cone-Wesson, 1987). The same testing protocol described above for neonates and infants through 4 months of age applies.

Assessment Protocol for Children Who Are Chronologically/Developmentally 25-36 Months of Age

Behavioral techniques, in combination with acoustic immittance measures, are generally sufficient for the comprehensive assessment of hearing for children in this age range. ABR is recommended when the validity or adequacy of behavioral test results are limited or the neurologic integrity of the auditory pathways to the level of the brainstem is in question.

**Behavioral assessment.** Conditioned play audiometry (CPA), tangible or visually reinforced operant conditioning audiometry (TROCA, VROCA), or visual reinforcement audiometry (VRA) should be employed, depending upon the child's ability to perform the necessary task. Frequency-specific thresholds should be determined at octave frequencies 500-4,000 Hz (at a minimum). Thresholds should be determined for each ear by air conduction. Bone-conduction thresholds should be determined when air-conducted thresholds are elevated. A threshold for speech using a closed set (picture-point, object-point, or repetition) response task should also be obtained. A formal assessment of word recognition ability using standardized tests such as Word Intelligibility by Picture Identification—WIPI (Ross & Lerman, 1971), the Northwestern University Children's Perception of Speech—NU-CHIPS (Elliot & Kak, 1980) and the Pediatric Speech Intelligibility Test—PSI (Jerger & Jerger, 1984) is recommended whenever appropriate. When the use of a standardized test is not possible, an attempt should be made to informally assess word recognition using objects or body parts within the child's demonstrated receptive vocabulary (Matkin, 1979; Olsen & Matkin, 1979). In the latter case, results should be reported descriptively and not quantitatively, as such tests are nonstandardized measures of word recognition ability.

**Personnel and Scope of the Assessment**

Audiologic assessment is performed by an ASHA-certified audiologist who is responsible for the administration and interpretation of behavioral, electrophysiologic, and acoustic immittance measures. Audiologic assessment includes the provision of input regarding audiologic follow-up and management including candidacy for use, fitting, and dispensing of amplification and/or alternative communication devices. Audiologic assessment also includes professional interpretation of case history and test results, parent/caregiver counseling, and, when appropriate, referral to allied professionals such as the primary care physician, medical specialist, speech-language pathologist, or psychologist. Where programs addressing the special needs of children with hearing impairment are in place, the audiologist and parent/caregiver are mandated members of the multidisciplinary team and participate in decisions regarding child and family needs (PL 99-457). Where no such programs are in place, guidance should be provided regarding available education and intervention options, so that the parent/caregiver can make informed decisions.

Guidelines for Screening for Hearing Impairment and Middle-Ear Disorders

The Guidelines for Screening for Hearing Impairments and Middle Ear Disorders were developed by the American Speech-Language-Hearing Association (ASHA) Working Group on Acoustic Imittance Measurements and the Committee on Audiological Evaluation and adopted by the ASHA Legislative Council (LC Z~9J in November 1989. The Working Group members were Robert H. Margolis, chair; Michael G. Block, Steven M. Pames; Ross J. Roeser; Janet E Shanks; and Richard H. Wilson. The Committee on Audiologic Evaluation members included Sandra Gordon-Salant, chair, Evelyn Cherow, current ex officio; John D. Durrant; Thomas E. Fowlkes; Thomas A. Frank; Gregg D. Givens; Michael P. Gorga; Carol Kamara, past ex officio; Sharon A. Lesner; and Laura Ann Wilber. The monitoring vice presidents were Gilbert R Herer past president and Teris K. Schery, current vice president for clinical affairs.

Introduction

In 1979, "Guidelines for Acoustic Imittance Screening of Middle-Ear Function" were published in Asha. Those guidelines, drafted by the Subcommittee on Impedance Measurement of the Committee on Audiologic Evaluation and approved by Legislative Council in November 1978, presented a procedure for determining pass-fail criteria that could be used to decide upon the need for retest or medical referral of individuals at risk for middle ear disorders. Recognizing the need for additional normative and clinical data, the subcommittee noted that the guidelines "should be considered as interim and subject to revision." The reconstituted subcommittee, now the ASHA Committee on Audiologic Evaluation - Working Group on Acoustic Imittance Measurements, has revised the guidelines with consideration for the following recent developments.

An American standard on aural acoustic immittance instruments has been completed (American National Standards Institute, 1987). This standard has already begun to influence the way aural acoustic immittance measurements are made. Technological advances have improved the instrumentation.

Many new instruments provide faster recording speeds, automatically compensate for ear-canal volume, and perform automatic calculations of tympanometric variables that are used as diagnostic indicators. New information on the natural course of otitis media provides important insight into the nature of the conditions that a screening protocol should detect. Clinical data on screening techniques, including the 1979 ASHA guidelines, are now available and shed new light on the outcomes of such screening strategies.

In 1985, a revised set of "Guidelines for Identification Audiometry" outlined a recommended procedure for audiometric screening for hearing impairment (ASHA, 1985). That document advised that "the pure-tone screening procedure should be part of a program which has, as a second component, acoustic immittance screening for identification of individuals who have middle ear disorders" (p. 52). ASHA recommends that screening programs include procedures for the detection of all peripheral auditory disorders, not just impairments of auditory sensitivity.

This document supersedes the "Guidelines for Acoustic Immittance Screening of Middle-Ear Function" (ASHA, 1979) and shall be used in conjunction with the "Guidelines for Identification Audiometry" (ASHA, 1985).

**Scope**

This document provides guidelines for identifying individuals with hearing impairments that potentially interfere with communication and/or individuals with potentially medically significant ear disorders that have been undetected or untreated. Individuals identified by the protocol described herein should, whenever possible, obtain an audiological evaluation and a medical examination. These guidelines can be used for individuals of all ages who can be tested by behavioral screening audiometry and tympanometry. They are, however, specifically designed for children and young adults (through age 40 years). Other ASHA guidelines address screening procedures for newborn infants (ASHA, 1988).

A thorough understanding of the basic principles of aural acoustic immittance measurement and identification audiometry is essential for competent design and execution of a screening protocol like the one described in these guidelines. A thorough review of acoustic immittance principles is beyond the scope of this document. Several recent reviews are available (Margolis, 1981; Margolis & Shanks, 1985; Shanks, Ully, Margolis, Wiley, 8 Wilson, 1988; Van Camp, Margolis, Wilson, Creten, 8 Shanks, 1986). For a review of the principles of identification audiometry, see ASHA (1985).

These guidelines recommend pass-fail criteria that are based, in part, on quantitative measurement of aural acoustic admittance.

Where first-generation acoustic immittance instruments provided results in relative ("arbitrary", units and careful calibration was less critical, current instruments present results in physical units. Careful, frequent calibration is essential.

Commercially available acoustic immittance instruments report tympanometric values in various units. Most currently available instruments measure the magnitude of acoustic admittance, which is properly reported in acoustic millimhos (mmho) or as an equivalent volume of air in cubic centimeters (cm³) or milliliters (ml). However, some manufacturers incorrectly refer to acoustic admittance as "compliance". With a properly calibrated instrument that employs a 226-Hz probe frequency, millimhos, cubic centimeters, and milliliters are equivalent units.

These guidelines are not intended as a recommendation for or against mass screening for middle-ear disorders or hearing loss. The arguments for and against such screening programs are reviewed by Bluestone et al. (1986). Methods for assessing screening programs are discussed by Cadman, Chambers, Feldman, and Sackett (1984). Although this document recommends specific pass-fail criteria, the criteria are not the only acceptable (and perhaps not always the best) choices. It may be appropriate and beneficial to modify the procedures and pass-fail criteria for specific populations and purposes. This document is intended as "guidelines" rather than a protocol that requires strict adherence.

Rationale

Recent studies of the effectiveness of recommended medical referral criteria from tympanometric results have demonstrated that excessive over-referral rates occur when the referral is based on the existence of abnormal tympanometric findings alone (Lous, 1983; Lucker, 1980; Roush & Tait, 1985). Consequently, referral criteria often include provisions for retest after a specified time interval (ASHA, 1979; Harford, Bess, Bluestone, & Klein, 1978) and the use of other screening measures along with tympanometry (Aniansson, 1986; Grimaldi, 1976; Margolis & Heller, 1987; Margolis & Shanks, 1985; Paradise & Smith, 1979; Van Camp, Shanks, & Margolis, 1986). Case history, otoscopic inspection, and audiometric screening frequently produce sufficient evidence of medically significant ear disorders without tympanometric results. To avoid the excessive overreferral rates that characterize screening protocols that are based solely on tympanometry, the screening protocol described in these guidelines includes four sources of data: history, visual inspection, identification audiometry, and tympanometry.

**History**

It is beyond the scope of a screening program to obtain a complete case history. However, recent occurrence of otalgia (ear pain) or otorrhea (ear discharge) is cause for immediate medical referral. The screening protocol, therefore, includes the acquisition of this information from the most appropriate respondent. It may be obtained at the time of the screening, or it may be requested (especially from parents) in advance of the screening. A request for this information can be included in a letter that explains the purpose of the screening program and requests parental approval for the child to be tested.

**Visual Inspection**

Visual evidence of ear disease may be evident to the unaided eye or revealed by otoscopy. Although it is not within the purview of this procedure to diagnose ear disease, the inclusion of visual inspection is expected to result in the identification of conditions that require medical attention that are not detected by other components of the screening battery. Because the skill and experience of the individual performing the otoscopic inspection will vary considerably, it is anticipated that more subtle visual evidence of middle-ear disorders will be detected in some screening programs and not in others. Three types of abnormalities should result in an immediate medical referral upon visual detection.

**Structural defects** of the ear, head, and neck should result in a medical referral. These include a wide variety of conditions such as abnormal position and/or structure of the external ear ranging from complete absence of the pinna and atresia of the ear canal to more subtle abnormalities such as malpositioned pinnae and preauricular pits and tags. The presence of visually detectable structural defects may portend the presence of other otologic abnormalities that require medical attention.

**Ear-canal abnormalities** including inflammation, blood, effusion, excessive cerumen, tumors, or foreign bodies in the ear canal are sufficient cause for a medical referral.

**Eardrum abnormalities** may be indicative of active middle-ear disorders that require immediate medical attention. Detection of these abnormalities, however, requires more skill and experience in otoscopy than the personnel administering this screening procedure can be expected to possess. In many cases the tympanic membrane is not visible even to an experienced otoscopist. Consequently, only the most obvious eardrum abnormalities are recommended as referral criteria. Obvious perforation, inflammation, or severe retraction of the tympanic membrane are criteria for immediate medical referral. The presence of a pressure-equalization tube indicates that the individual is in the medical treatment/follow-up process. Evaluation of these individuals is, therefore, outside the scope of this screening recommendation.

Identification Audiometry

Although audiometric screening is not adequate for detecting all medically significant otologic disease (Eagles, Wishik, & Doerfler, 1967), identification audiometry is included in this screening protocol for two reasons. First, the existence of hearing loss in association with other abnormal tympanometric results is evidence of a significant medical and communicative disorder. Whereas abnormal tympanometry alone requires a retest to avoid overreferrals associated with transient, self-correcting otitis media, concomitant hearing loss requires immediate follow-up. Second, the inclusion of audiometry in the screening protocol provides the capability to detect sensori-neural hearing loss. Consequently, screening audiometry in accordance with the ASHA Guidelines for Identification Audiometry (ASHA, 1985) is included in the screening procedure.

Acoustic Immittance Measurements

In the absence of significant otologic history, visual evidence of middle-ear disorders, and hearing loss, tympanometry abnormalities may result from middle-ear conditions that do not represent medically significant pathology. The transient, self-correcting, secretory otitis media that frequently occurs in children does not often require medical attention (Fiellau-Nikolajsen, 1983; Tos & Poulsen, 1979), and medical referral of these children represents a potentially unacceptable overreferral rate. Tympanometric abnormalities, then, must be interpreted with caution, ensuring referral of conditions requiring medical intervention while avoiding excessive overreferral. The utility of five immittance variables is discussed below, in the context of the four-part screening protocol.

**Static admittance** (Peak Y) is a measure of the height of the admittance-magnitude tympanogram relative to the tail value. Although the classification of tympanometric shapes has been more commonly employed for determining abnormalities, static admittance can enhance the reliability of the classification of shape. That is, static admittance can be used as an objective criterion for categorizing the shape of a tympanogram. Because the majority of tympanograms recorded with a 226-Hz probe frequency are single-peaked (Van Camp, Creten, Van de Heyning, Deeraemer, & Vanpeperstraete, 1983), the classification of tympanometric shapes is based primarily on peak height, that is, static admittance. The distinctions among Type A, Type As, Type Ad, and Type C tympanograms in the Liden, Jerger classification system (Jerger, 1970; Uden, 1969) can be made more reliable within and among clinicians by using an objective criterion. For screening instruments that use a +200 daPa ear canal volume correction and 200 daPa’s pump speed, interim norms are presented in Appendix A. High static admittance is caused by eardrum and ossicular abnormalities. Eardrum abnormalities that cause high static admittance are rarely associated with active disease or hearing loss.

Significant ossicular abnormalities are typically associated with large conductive hearing losses. High static admittance, then, in the absence of other signs, is not cause for medical referral. Only low static admittance is employed in these guidelines as a referral criterion.

**Equivalent ear-canal volume** (Vec) is an estimate of the volume of air in front of the acoustic-immittance probe. It is obtained by measuring the admittance at high positive or high negative ear-canal air pressure. Vec is useful for detecting tympanic membrane perforations accompanied by normal middle-ear mucosa. When perforations are accompanied by inflammation of the middle ear, Vec may not be abnormally large (Margolis & Shanks, 1985). When measured at an ear-canal air pressure of 200 daPa, a Vec value that exceeds the 90% range given in Appendix A, when accompanied by a flat tympanogram, is sufficient cause for immediate medical referral. Although many tympanic membrane perforations do not produce abnormal Vec values, these middle-ear abnormalities will be detected by other tympanometric variables, by pure-tone audiometry, and/or by otoscopy.

**Tympanometric width** is a quantity that belongs to the class of measurements referred to as tympanometric gradient. Gradient measures are used to describe the shape of the tympanogram in the vicinity of the peak. Measures of this type have been shown to be good indicators of middle-ear effusion (Fiellau-Nikolajsen, 1983; Haughton, 1977; Paradise, Smith, & Bluestone, 1976). Several studies have evaluated the normative distribution characteristics of various gradient measures (De Jonge, 1986; Koebelski & Margolis, 1986; Shanks & Wilson, 1986). On the basis of these results, the gradient measure first described by Uden and his colleagues (Uden, Harford, & Hallen, 1974; Liden, Peterson, & Bjorkman, 1970) appeared to be the procedure of choice. They calculated the pressure interval corresponding to a 50% reduction in peak (static) admittance (the tympanometric width, TOO). That measure appeared to be superior to other gradient measures on the basis of (a) normative distribution width in relation to the range of possible values; (b) invariance with pump speed, and (c) low correlation with (and, therefore, supplemental to) static admittance. Gradient measures seem to be sensitive to disease-related mechanical changes in the middle ear that are not always detected by other tympanometric measures or by otoscopy. Although clinical data are not yet available for tympanometric width, previous studies of patient populations suggest that tympanometric gradient measures are good indicators of middle-ear effusion. Accordingly, the 90% ranges in Appendix A are tentatively recommended as a criterion for medical referral. These values are relevant only to instruments that determine static admittance relative to the admittance at 200 daPa Gradient measures have been primarily used for the detection of otitis media, which produces abnormally wide tympanograms. Consequently, for the purposes of these guidelines, only abnormally large tympanometric widths will be considered as a criterion for medical referral.

Tympanometric peak pressure (TPP) is an indirect measure of the air pressure in the middle ear. Large, negative intratympanic pressures have been attributed to gas absorption in the middle ear associated with failure of the eustachian tube to open. Negative TPP, then, would be indicative of early stages of otitis media. However, this "ex vacuo" theory has recently been challenged (Buckingham & Ferrer, 1980; Bylander, Ivarsson, TJernstrom, & Andreasson, 1985; Hergils & Magnuson, 1987). Experimental evidence suggests that gas absorption, by itself, does not account for the large negative pressures observed in some ears. Gas absorption that occurs when the eustachian tube is chronically closed produces pressures that are rarely more negative than -100 daPa (Cantekin, Doyle, Phillips, & Bluestone, 1980; Proud, Odoi, & Toledo, 1971; Yee & Cantekin, 1986). Mechanisms that have been proposed to account for larger negative intratympanic pressures include alteration of the normal gas absorption rate due to a disturbance in the composition of middle-ear gases (Cantekin et al., 1980), ciliary action of the closed eustachian tube (Hilding, 1944; Murphy, 1979), and sniffing (Falk, 1983; Magnuson, 1981). Positive intratympanic pressures may occur in early stages of acute otitis media (Ostergard & Carter, 1981; Paradise et al., 1976) due to a reduction of middle-ear volume by effusion or by diffusion of gases from the infected tissue into the middle-ear space. In view of the several mechanisms that produce middle-ear pressure and the fact that TPP is an imprecise estimate of the actual middle-ear pressure p/an Camp, Margolis, Wilson, Creten, & Shanks, 1986), it is not surprising that negative TPP associated with an otherwise normal tympanogram is a poor determinant of middle-ear effusion (Fiellau Nikolajsen, 1983; Haughton, 1977; Paradise et al., 1976). Furthermore, abnormal TPP in the absence of other tympanic membrane abnormalities does not reflect a change in the mechanical properties of the middle ear, only a change in its operating point. For these reasons, and because of the large fluctuations in TPP that have been shown to occur in children who do not develop middle-ear disorders (de Jonge & Cummings, 1985; Uldholdt, 1980), TPP may be judiciously excluded from consideration as a criterion for audiological/medical referral.

Acoustic reflex (AR) measures have been used in screening protocols for middle-ear disorders (ASHA, 1979; Brooks, 1968, 1969, 1974; Harford et al., 1978; McCandless & Thomas, 1974). Although acoustic-reflex thresholds are effective in detecting sensorineural hearing loss in the presence of normal middle-ear function (Popelka, 1981), the efficacy of acoustic-reflex measurements for detecting middle-ear disorders is limited.

An absent acoustic reflex may result from (a) a reduction in input to the reflex mechanism due to a middle-ear disorder, (b) a reduction in transmission through the afferent pathway due to sensorineural hearing loss, (c) abnormal function of the efferent portion of the reflex arc due to brainstem or facial nerve disease, or (d) a mechanical disturbance in the middle ear that reduces or eliminates the impedance change that normally results from muscle contraction. Often a combination of these factors operates. In evaluating middle-ear abnormalities, the acoustic-reflex measurement is an indirect index of the status of the middle ear that is more directly assessed with tympanometry. These considerations and their extensive examination of screening programs led several investigators to recommend against the inclusion of acoustic-reflex measurements in screening for middle-ear disorders in children (Cantekin et al., 1980; Renvall, Uden, Jungert, & Nilsson, 1975; Wachtendorf, Lopez, S3ooper, Hearn, & Gates, 1984). The use of acoustic reflex measures contributed to the unacceptably high false positive rates reported in previous assessments of screening protocols (Lous, 1983; Roush & Tait, 1985). AR is not incorporated in the screening protocol described below.

**Equipment**

The screening protocol requires an otoscope, a puretone audiometer, and an acoustic immittance instrument. The audiometer should be calibrated in accordance with the audiometer standard (ANSI S3.6-1969). The acoustic immittance instrument should comply with the ANSI standard on aural acoustic immittance instruments (ANSI S3.39-1987). It should measure acoustic admittance in acoustic millimhos (mmho). Alternatively, acoustic admittance may be expressed in equivalent volume of air in cubic centimeters (cm) or milliliters (ml). A number of procedural variables influence the values obtained from tympanograms (see Shanks et al., 1988, for a comprehensive review). The normative admittance data presented in Appendix A pertain to instruments that employ a 226-Hz probe frequency, a pump speed of 200 daPa/s, a positive-to-negative direction of pressure change, and correct for ear-canal volume by subtracting the admittance at 200 daPa from the remaining admittance values. If other measurement parameters are employed, appropriate norms must be used. The data in Appendix A should be considered as interim norms pending a badly needed, large-scale normative study of aural acoustic immittance. Clinical programs may wish to determine their own norms.

Three acoustic immittance measures are used in the screening protocol: static admittance, equivalent ear-canal volume, and tympanometric width. The calculation methods used to obtain these measures will substantially influence the values. Static admittance is calculated by subtracting an estimate of the admittance of the ear-canal volume from the peak admittance. The ear-canal volume estimate is obtained from one of the tail values of the tympanogram.

Acoustic immittance instruments that automatically calculate static admittance differ in the choice of ear canal volume correction. Screening instruments typically use the value at +200 daPa whereas clinical instruments often provide a choice.

Equivalent ear-canal volume is obtained from the admittance at the positive or negative tail of the tympanogram. Because of the asymmetry that characterizes most tympanograms, the tail values from the positive pressure side of the tympanogram tend to be greater than those obtained from the negative pressure side. Interim normative values are presented in Appendix A for equivalent ear-canal volume estimated at +200 daPa.

Ideally, tympanometric width (TOO) would be calculated automatically by the instrument. When it is not, a template can be constructed that allows graphic determination of normal and abnormal values. Examples of templates for evaluating TW are shown in Appendix B. The method of correcting for ear-canal volume affects TW because the peak value, required in the calculation, is determined after ear-canal correction. The interim normative values for TW in Appendix A pertain to estimates obtained with the 20 daPa ear-canal volume correction.

**Personnel**

Because screening programs are designed to test large numbers of subjects, the test procedures may be conducted by personnel who are not clinical audiologists. The screening protocol described in these guidelines, however, should be supervised by a clinical audiologist who has training and experience related to the test procedures that comprise the protocol. The personnel who administer the protocol should be sufficiently trained in the procedures to obtain accurate and reliable results.

**Recommended Screening Protocol**

The recommended screening protocol is based on a four-part procedure consisting of case history, visual inspection, pure tone audiometry, and tympanometry. Referral criteria are presented in Table 1. The protocol is presented in flow chart format in Figure 1. The flow chart is a representation of the logic used to determine the need for referral. It does not represent the order in which test procedures are administered. With the exception that visual inspection should precede tympanometry, the order of test procedures is unimportant. Each test component, indicated by a numbered box in Figure 1, is described below.

Figure 1.
Flow chart for determination of the need for audiologic/medical referral incorporating case history, visual inspection, pure-tone audiometry, and tympanometry. Each numbered box is discussed in the text. The flow chart represents the logic used to determine the need for referral. It does not indicate the order of test procedures.

Table 1
Referral Criteria

I. History
   A. Otalgia
   B. Otorrhea

II. Visual Inspection of the Ear
   A. Structural defect of the ear, head, or neck
   B. Ear canal abnormalities
      1. Blood or effusion
      2. Occlusion
      3. Inflammation
      4. Excessive cerumen, tumor, foreign material
   C. Eardrum abnormalities
      1. Abnormal color
      2. Bulging eardrum
      3. Fluid line or bubbles
      4. Perforation
      5. Retraction

III. Identification Audiometry - Fail air conduction screening at 20 dB HL at 1, 2, or 4 kHz in either ear (ASHA, 1985; these criteria may require alteration for various clinical settings and populations).

IV. Tympanometry
   A. Flat tympanogram and equivalent ear canal volume (Veq) outside normal range
   B. Low static admittance (Peak Y) on two successive occurrences in a 4-6-week interval
   C. Abnormally wide tympanometric width (TW) on two successive occurrences in a 4-6-week interval

1. A recent otologic history of otalgia or otorrhea is sufficient cause for immediate medical referral.

2. Visual inspection of the ear may produce sufficient cause for medical referral without the need for further testing. Referral criteria include: structural defect of the ear, head, or neck; inflammation, blood, effusion, excessive cerumen, tumors, or foreign body in the ear canal; or eardrum appearance consistent with active middle-ear disease. When visual inspection indicates the need for medical referral, tympanometry is not necessary. When visual evidence of middle ear infection is present, or when a pressure-equalization tube is in place, tympanometry should not be performed unless requested by a physician.

3, 4. Audiometric screening should be performed by the method described in the ASHA Guidelines for Identification Audiometry (ASHA, 1985). Those guidelines recommend screening with pure-tone stimuli presented at 20 dB HL (re: ANSI S3.6-1969) with frequencies of 1000, 2000, and 4000 Hz. Failure to respond to any frequency constitutes failure of the audiometric screen. In accordance with the Identification Audiometry Guidelines, failure of the audiometric screen should be confirmed by a rescreen, either on-site or by additional testing at a later date. If the audiometric screen is failed on the second administration, a complete audiologic evaluation should be performed.

5, 6. Low static admittance (Peak Y) associated with an abnormally large volume in front of the probe is evidence of a tympanic membrane perforation and warrants immediate referral. The presence of (Vec) (estimated at 200 daPa) exceeding the 90% range in Appendix A in the presence of a flat tympanogram is evidence of a large volume and should result in a medical referral.

7. Low static admittance (Peak Y) may or may not be associated with significant middle-ear disorders. In the absence of other positive findings, a Peak Y below the 90% range in Appendix A requires observation over an extended period before a medical referral is warranted. Only after two successive abnormal findings over an interval of 4-6 weeks should medical referral be made.

8, 9. An abnormally wide tympanometric width (TOO) may occur in the absence of other findings in cases with otitis media. These cases may represent transient secretory otitis media, which does not require medical referral. Like static admittance, abnormal TW in the absence of other signs of middle-ear disorders requires retest after +6 weeks, and only then should a medical referral be based on this finding alone.

**Audiologic or Medical Referral**

Failure of the screen should result in an audiologic evaluation and a medical examination. The nature of the referral may depend upon the characteristics of the screening program and the availability of services. For example, the referral may be to a clinic that provides both audiologic and medical services. Alternatively, an audiologic referral may precede the medical referral. If audiologic services are not available, an immediate medical referral should be made upon failure of the screening protocol.

CLINICAL MASKING HANDOUTS
Includes masking paradigm and supplemental readings
INTERAURAL ATTENUATION (IA)

Interaural attenuation is the difference between the intensity of an acoustic event at the sound source, usually near the test ear, and the intensity, or amount of energy, received in the non-test ear and heard by the observer. It is a measure of sound energy lost during acoustic crossover.

MASKING

The interference of a wanted or unwanted sound by another sound. In clinical audiology this refers to the interference of a sound in the same ear. That is, the interference of a target sound by a non-target sound, or the interference of a non-target sound by a target sound. The usually refers to the use of masking noise as the non-target sound and a puretone or speech and the target sound.

CARDINAL RULE FOR MASKING

Masking MUST be used whenever the target stimulus is intense enough to crossover, either by air conduction or bone conduction, and be heard in the non-test ear.

FACTORS IN MASKING

1. Interaural attenuation.
2. Bone conduction threshold of the non-test ear.
MASKING CONSIDERATIONS

1. The amount of masking needed is that just enough to prevent the non-test ear from participating in the test. This is called MINIMUM masking, or the amount of noise needed to just mask the acoustic stimulus.
2. When the masking itself is intense enough to crossover and is heard in the test ear it is termed OVERMASKING. Overmasking is when the masking stimulus interferes with the test ear or target stimulus (i.e., it shifts the threshold in the test ear).
3. The amount of masking that is just below the overmasking value is termed MAXIMUM masking. If the masking intensity were increased then overmasking would occur and the masking stimulus would crossover to the test ear.
4. UNDERMASKING occurs whenever the masker is below the minimum masking level. Undermasking does not prevent the non-test ear from participating in the hearing test and is therefore not effective.
5. Masking errors occur whenever under masking or over masking occurs. Both are very serious and cause errors in threshold testing thus the hearing appears better. Undermasking will UNDER estimate the hearing threshold, and overmasking will OVER estimate the hearing threshold thus hearing appears worse. Both result in misdiagnosis and the possibility of inappropriate amplification, educational placement and planning, and labeling.
6. EFFECTIVE MASKING LEVEL is that level which a masker will mask the non-test ear without crossing over. It is considered any value between minimum and maximum masking levels. In using the “plateau” method of masking this would be identified as the plateau region of the slopes.

MINIMUM MASKING LEVEL

The minimum masking level may be estimated by adding the amount of acoustic crossover (the intensity of the test tone minus the interaural attenuation) and adding it to the air-conduction threshold of the masked ear (i.e., non-test ear for the type of stimulus used to mask the stimulus in the test ear).

MAXIMUM MASKING LEVEL

The maximum masking level may be estimated by adding the interaural attenuation for air-conduction (i.e., 40 dBHL) to the bone conduction threshold of the test ear (usually assumed to the “best bone conduction” response, or the unmasked bone conduction threshold). **The maximum masking level will change as testing progresses.**

CENTRAL MASKING

It is not unusual for a threshold shift of approximately 5 dB to occur whenever masking is introduced into the contralateral ear. This is due to the effects of the crossed pathway and the central auditory system. Although it may be technically correct to subtract this value from the masked threshold it is not recommended, and if done should be stated on the audiogram. The exact value and the presence of central masking is variable and does
not represent a reliable measure in the hearing population, and is not predictable in a hearing impaired population.

OCCLUSION EFFECT

The occlusion effect occurs for low frequency bone conduction sounds (up to about 1000 Hz to 1500 Hz). When an ear is occluded, such as with an earphone, the bone conducted sound is heard louder in the occluded ear. This is due to impedance changes in the occluded ear making the cochlea appear more “sensitive”. In the case of clinical masking this will make the bone conduction sound louder in the masked, or non-test ear. Consequently, after placing the masking earphone over the non-test ear, the bone conduction threshold should be re-evaluated and the new bone conduction thresholds used to determine effective masking levels. Each frequency must be considered separately.

CLINICAL TESTING NOTE

Life is much easier if the clinician will make a few simple modifications to the test routine. First, complete immittance audiometry first, or minimally tympanometry. This will most all middle ear problems and alert you to the extent masking may be needed. Second, complete bone conduction, unmasked PRIOR to air-conduction testing. It will provide you with information as to whether masking will be needed for air-conduction testing, it provides you with the ability to estimate the maximum masking level, and correction thresholds for the occlusion effect. However the clinician must remember that when prioritizing an audiological evaluation or procedure the actual sequence is dictated by the subject and that procedure which will be least invasive and intrusive on behavior (McPherson’s cardinal rule for excellence in audiology).

WHERE TO START MASKING

Masking may always be started at 30 dBHL and the plateau method followed from that point forward. However a better staring level is at 30 dBSL relative to best unmasked bone conduction. The plateau method, by virtue of the physics of the auditory system, is a “whole” system response and accounts for the majority of problems encountered in masking without needed extensive calculations. It is the preferred method of masking.

PLATEAU METHOD OF CLINICAL MASKING

The plateau method, by virtue of the physics of the auditory system, is a “whole” system response and accounts for the majority of problems encountered in masking without needed extensive calculations. It is the preferred method of masking.

A. Established unmasked thresholds for b/c and a/c in both ears.
B. Adjust the continuous masking level to either 30 dBHL or 30 dBSL in the non-test ear (in clinical masking the masking stimulus will always assumed to be in the non-test ear).

C. Re-establish the threshold in the test ear.
   1. If threshold shows shifts (shift always means worse, or the dBHL for threshold increases):
      a. The masking has decreased the participation of the non-test ear; or
      b. Overmasking has occurred.
   2. If the threshold does not shift:
      a. The threshold is a “shadow” produced by undermasking in the non-test ear (i.e., the non-test ear is participating in the threshold of the test ear); or
      b. The actual threshold in the test ear has been achieved; or
      c. Masking was not needed and the actual threshold in the test ear has been achieved.

D. Increase the masking by 10 dB.
   1. If threshold shows shifts (shift always means worse, or the dBHL for threshold increases):
      a. The masking has decreased the participation of the non-test ear; or
      b. Overmasking has occurred.
   2. If the threshold does not shift:
      a. The threshold is a “shadow” produced by undermasking in the non-test ear (i.e., the non-test ear is participating in the threshold of the test ear); or
      b. The actual threshold in the test ear has been achieved.

E. Increase the masking by 10 dB.
   1. If threshold shows shifts (shift always means worse, or the dBHL for threshold increases):
      a. The masking has decreased the participation of the non-test ear; or
      b. Overmasking has occurred.
   2. If the threshold does not shift:
      a. The threshold is a “shadow” produced by undermasking in the non-test ear (i.e., the non-test ear is participating in the threshold of the test ear); or
      b. The actual threshold in the test ear has been achieved.

F. Increase the masking by 10 dB.
   1. If threshold shows shifts (shift always means worse, or the dBHL for threshold increases):
      a. The masking has decreased the participation of the non-test ear; or
      b. Overmasking has occurred.
   2. If the threshold does not shift:
      a. The threshold is a “shadow” produced by undermasking in the non-test ear (i.e., the non-test ear is participating in the threshold of the test ear); or
      b. The actual threshold in the test ear has been achieved.
G. Increase the masking by 10 dB.
   1. If threshold shows shifts (shift always means worse, or the dBHL for threshold increases):
      a. Overmasking has most likely occurred.
   2. If the threshold does not shift:
      b. The actual threshold in the test ear has been achieved.
H. Another increase in masking by 10 dB should produce an increase in threshold thereby indicating overmasking. However, the plateau may have a spread from 15 to 35 dB depending on the frequency being tested and variability in the physics of the process.

If a plateau is NOT achieved there is not an absolute way to assure “true” threshold. This occurs sometimes in extreme masking problems such as bilateral conductive hearing loss with sensorineural components and various types of bilateral and unilateral combinations. Impittance audiometry is the best defense in determining the extent of the masking problem at hand.

CLINICAL MASKING

Clinical masking of the non-test ear during pure-tone and speech-recognition threshold testing, assessment of speech recognition ability, and site-of-lesion testing (except for acoustic immittance) is often necessary to prevent the responses of the non-test ear from contaminating the responses of the test ear. In some cases, when testing the test ear by air-conduction or bone-conduction, the non-test rather than the test ear will respond to the stimulus. Masking is a noise which is presented to the non-test ear to elevate the threshold in that ear.

A. INTERAURAL ATTENUATION

1. BONE CONDUCTION

A signal presented through a bone-conduction oscillator or through an earphone can cross from the test ear to the non-test cochlea by bone conduction. That is, a signal presented to the test ear causes vibration of the skull so sound travels through the skull bones to the non-test cochlea. Consequently, the better cochlea responds to the stimulus regardless of which ear is being tested by bone conduction. The bone-conducted stimulus crosses from the test ear to the non-test cochlea without loss of intensity at the low frequencies and with a slight loss of intensity at the high frequencies. The loss of intensity as the sound travels from the test to the non-test ear is referred to as interaural attenuation (Chaiklin, 1967).


The interaural attenuation for bone-conducted stimuli with mastoid placement of the bone oscillator ranges from approximately 0 dB at 250 HZ to approximately 15 dB at 4000 HZ (Studebaker, 1967). Our clinical
experience shows that the interaural attenuation for bone-conduction at 2000 and 4000 Hz ranges from 0 to 15 dB. At the low frequencies, the skull vibrates as a whole so the signal crosses by bone conduction through the skull unattenuated. At the high frequencies, the temporal bone vibrates first; then the whole skull vibrates segmentally. The interaural attenuation for bone-conducted stimuli with forehead placement of the bone oscillator is approximately 0 dB (Studebaker, 1967).

The passage of sound from the test to the nontest ear is referred to as crossover. Crossover, however, is not synonymous with crosshearing (also described as transcranial hearing or shadow hearing). Crosshearing occurs only if the sound which arrived at the nontest cochlea by crossover from the test ear is heard by the nontest cochlea. For example, if a sound is presented by bone conduction at 50 dB HL at 250 Hz in the test ear, it will cross over to the nontest cochlea at 50 dB HL (that is, there is 0 dB interaural attenuation). If the nontest cochlea has a bone-conduction threshold of 70 dB HL at 250 Hz, that cochlea will not be sensitive to the sound that crossed over so crosshearing does not occur, that is, despite the crossover resulting in the presence of a 50-dB sound at the nontest cochlea, crosshearing does not occur. On the other hand, if the nontest cochlea has a bone-conduction threshold of 50 dB HL at 250 Hz, that cochlea will be sensitive to the sound that crossed over so crosshearing will occur at threshold (i.e., 0 dB SL), so the crossover resulting in the presence of a 50-dB sound at the nontest ear is accompanied by crosshearing. If the nontest cochlea has a bone-conduction threshold of 20 dB HL, that cochlea will be sensitive to the sound that crossed over, so crosshearing will occur at 30 dB SL re: bone-conduction threshold in the nontest ear (50 dB crossover level - 20 dB bone-conduction threshold in the nontest ear).

The following example illustrates the interaural attenuation for bone conduction at the high frequencies. Suppose that a 55 dB HL sound is presented by bone conduction to the right ear. The sound will cross over to the left cochlea at 40 dB HL, that is, there is 15 dB interaural attenuation. If the left cochlea has a bone-conduction threshold of 30 dB HL at 4000 Hz, it will be sensitive to the sound that crossed over, so crosshearing will occur at 10 dB SL re: bone conduction threshold in the left ear (40 dB HL crossover level - 30 dB HL bone-conduction threshold). The 0 dB interaural attenuation for bone conduction at the low and mid frequencies has implications for the bone conduction testing procedure. Only one ear need be tested by bone conduction in the unmasked condition since the better cochlea will respond regardless of which ear is being tested, so the unmasked bone-conduction threshold will be the same regardless of which ear is being tested by bone conduction at the low and mid frequencies.


The interaural attenuation for bone conduction at the high frequencies can, in some cases, assist the clinician in determining when the unmasked bone-conduction thresholds for both the right and left ears should be obtained. If the bone oscillator is routinely placed on the
ear with the better air-conduction threshold, time will often be wasted in obtaining the unmasked bone-conduction threshold of both ears as illustrated in Figure 16. As Figure 16 shows, if the better (left) ear has an air-conduction threshold of 30 dB HL at 4000 Hz, the poorer (right) ear has an air-conduction of 50 dB HL at that frequency, and the bone oscillator is placed on the better ear (yielding an unmasked bone conduction threshold of 30 dB HL), a significant unmasked air-bone gap will be present for the poorer (right) ear. Therefore, the clinician will need to obtain the unmasked bone-conduction threshold for the right as well as the left ear to determine whether the masked bone-conduction threshold is needed for the right ear. Often in these cases the unmasked bone-conduction threshold with the bone vibrator on the poorer ear is similar to the air-conduction threshold of the poorer ear. Thus, if the bone oscillator is placed on the ear with the poorer air-conduction threshold, unnecessary measurement of the unmasked bone-conduction thresholds for both the right and left ears will be avoided. In the example just given, if the bone oscillator is placed on the poorer (right) ear rather than the better (left) ear, the unmasked bone-conduction threshold might be 45 dB HL instead of 30 dB HL, so the unmasked bone-conduction threshold would not have to be obtained for the left ear also (see Figure 16B).). Nevertheless, if at 2000 or 4000 Hz the unmasked bone-conduction threshold (bone oscillator placed on the poorer ear) minus 15 dB (maximum interaural attenuation for bone conduction) results in a significant unmasked air-bone gap in the better ear, then the unmasked bone-conduction threshold should also be obtained with the bone oscillator placed on the ear with the better air-conduction threshold at these frequencies. It is otherwise unnecessary to obtain the unmasked bone-conduction threshold with the bone oscillator placed on the better ear. Thus, in some situations, when the bone oscillator is placed on the poorer ear, the unmasked bone conduction threshold at 2000 or 4000 Hz may reflect the true bone-conduction threshold of the poorer rather than the better ear. When the bone oscillator is placed on the better ear at 2000 or 4000 Hz, the unmasked bone conduction threshold will reflect the true bone-conduction.

Figure 16 (A) Audiogram for a patient with a bone oscillator placed on the left, better ear. The unmasked bone-conduction thresholds and the air-conduction thresholds for both ears are shown. (B) Audiogram for the same patient with the bone oscillator placed on the right, poorer ear. The unmasked bone-conduction thresholds and air-conduction thresholds for both ears are shown.

threshold of the better ear. At the other test frequencies, regardless of whether the bone oscillator is placed on the poorer or the better ear, it can be assumed that the unmasked bone-conduction threshold reflects the true bone conduction threshold of the better ear.


2. AIR CONDUCTION

According to Bekesy (1948), a signal presented at high intensities through the test earphone can leak from under the
rubber cushions and cross over to the non-test earphone. That is, the mechanism for crossover during air-conduction testing is by around-the-head (air conduction) leakage rather than through-the-head (bone conduction) transmission. Other investigators have contended that, for air-conduction testing, crossover occurs by means of the bone-conduction mechanism (Sparrevohn, 1946; Studebaker, 1962; Wegel & Lane, 1924; Zwislocki, 1953). That is, when a sound is presented by air conduction to the test ear, it will be transmitted through the skull bones to the non-test cochlea. Chaiklin (1967) suggested that crossover from the test to the non-test ear for strong air-conducted stimuli occurs through the bone-conduction (through-the-head) as well as the air-conduction (around-the-head) mechanism. In the process, the sound will be attenuated by 40 dB because sound has to travel from the air into the skull. According to Chaiklin (1967), crossover by the bone-conduction mechanism occurs before crossover by the air-conduction mechanism at most frequencies. Thus, air-conducted stimuli presented to the test ear will cross over first by the bone-conduction mechanism and then by the around-the-head mechanism to the non-test ear regardless of the type or magnitude of hearing loss in the test ear. Thus, the intensity at the cochlea of the non-test ear depends only on the intensity at the external auditory meatus of the test ear and the interaural attenuation for air-conducted stimuli from the test to the non-test ear.

The interaural attenuation for air-conducted stimuli can be determined by obtaining the unmasked air-conduction thresholds bilaterally in patients with complete unilateral deafness and 0-10 dB HL air- and bone-conduction thresholds in the normal-hearing ear, and then subtracting the good-ear air-conduction thresholds from the poor-ear air-conduction thresholds. The intensities at which responses are obtained reflect cross-hearing as well as crossover in the normal-hearing, non-test ear.

Table X shows the unmasked air-conduction threshold levels for both ears of subjects with unilateral deafness presented by Chaiklin (1967). As can be seen from this table, a tone of 70 dB SPL at 500 Hz presented to the dead ear is heard in the non-test ear at 11 dB SPL. Thus, the interaural attenuation for air-conduction at 500 Hz is 59 dB on average, with a minimum value of 54 dB and a maximum value of 65 dB. The average, minimum, and maximum interaural values for air-conduction at each frequency are also shown in Table X. The minimum interaural attenuation at frequencies between 250 and 8000 Hz found by Chaiklin (1967) was 44 dB at 250 Hz. Note that the interaural attenuation for air-conducted stimuli increases directly with frequency. The maximum interaural attenuation for air-conduction stimuli reported by Chaiklin (1967) was 85 dB at 4000 Hz. Liden, Nilsson, and Anderson (1959b) reported minimum interaural attenuation values for air-conducted stimuli of 45-50 dB at 250-8000 Hz.

Coles and Priede (1968) reported minimum interaural attenuation values for air-conducted stimuli of 40-50 dB at 250-4000 Hz. Thus, the smallest interaural attenuation value for air-conducted stimuli reported by any investigator is 40 dB. It is recommended that, for clinical purposes, the interaural attenuation value for air-conducted stimuli be considered as 40 dB to minimize the possibility of crosshearing.

### B. WHEN TO MASK

When masking is required, masking noise is introduced into the nontest ear while testing the test ear. The purpose of the masking noise is to shift the air- and bone-conduction threshold in the nontest ear so there will not be crosshearing in the nontest ear. The masking noise used during pure-tone air- and bone-conduction testing is narrow-band noise presented through the earphones. The masking noise used during speech-recognition (suprathreshold and threshold) testing is speech noise presented through the earphones. (For further details about the masking noises, or maskers, see Chapter 1.)

#### 1. BONE-CONDUCTION THRESHOLD MEASUREMENT

The masked bone-conduction threshold for the test ear should be obtained whenever the air-bone gap in the test ear exceeds 10 dB. Narrow-band noise is introduced into the nontest ear and the masked bone-conduction threshold is established for the test ear. Figure 17 shows an audiogram of the unmasked bone-conduction thresholds and air-conduction thresholds at 250, 500, and 1000 Hz.

The masked bone-conduction thresholds need to be obtained for the left ear at 250 Hz, where there is a 15-dB air-bone gap, for the right ear at 500 Hz, where there

### Table X  Mean Thresholds for Each Ear with Phones and Interaural Attenuation

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Mean thresholds (dB SPL)</th>
<th>Interaural attenuation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deaf ear</td>
<td>Better ear</td>
</tr>
<tr>
<td>125</td>
<td>87</td>
<td>49</td>
</tr>
<tr>
<td>250</td>
<td>77</td>
<td>26</td>
</tr>
<tr>
<td>500</td>
<td>70</td>
<td>11</td>
</tr>
<tr>
<td>750</td>
<td>74</td>
<td>5</td>
</tr>
<tr>
<td>1000</td>
<td>66</td>
<td>5</td>
</tr>
<tr>
<td>1500</td>
<td>73</td>
<td>6</td>
</tr>
<tr>
<td>2000</td>
<td>69</td>
<td>8</td>
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<td>3000</td>
<td>75</td>
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<tr>
<td>4000</td>
<td>73</td>
<td>3</td>
</tr>
<tr>
<td>6000</td>
<td>83</td>
<td>18</td>
</tr>
<tr>
<td>8000</td>
<td>76</td>
<td>19</td>
</tr>
</tbody>
</table>

* Modified from Chaiklin (1967).
is a 25-dB air-bone gap, and for both ears at 1000 Hz, where there is a 15-dB air-bone gap in the left ear and a 40-dB air-bone gap in the right ear. At 250 Hz, the masked bone-conduction threshold is established for the left ear and masking noise is introduced into the right ear. At 500 Hz, the masked bone-conduction threshold is established for the right ear and masking noise is introduced into the left ear. At 1000 Hz, the masked bone-conduction threshold is established for either the right or left ear first with masking noise in the opposite ear. If the masked bone-conduction threshold for the first ear tested (e.g., the right ear) shifts significantly (by more than 10 dB), it is not necessary to obtain the masked bone-conduction threshold for the other (left) ear; it is assumed, in such cases, that the unmasked bone-conduction threshold reflects the true bone-conduction threshold of the other (left) ear. If there is no shift in the masked bone-conduction threshold of the initial (right) ear, then the masked bone-conduction threshold must also be obtained for the other left ear.)

2. AIR-CONDUCTION THRESHOLD MEASUREMENT

The masked air-conduction threshold is needed for the test ear if the air-conduction threshold for the test ear exceeds the true bone-conduction threshold (or air – conduction threshold, whichever is lower) of the nontest ear by at least 40 dB. If the masked air-conduction threshold is needed, masking noise is introduced into the nontest ear and the masked air-conduction threshold is established for the test ear. Because the decision to obtain the masked air-conduction threshold depends on knowledge of the true bone-conduction thresholds, masking for bone conduction should be done before masking for air conduction. Figure 18 shows an audiogram with the masked and unmasked bone-conduction thresholds and unmasked air-conduction thresholds at 1000, 2000, 4000, and 8000 Hz.

The masked air-conduction threshold is needed at 1000 Hz, where there is a 50-dB difference between the right air-conduction threshold and the left masked bone-conduction threshold, at 2000 Hz, where there is a 40-dB difference between both air-conduction thresholds and both masked bone-conduction thresholds, at 4000 Hz, where there is a 40-dB difference between the left air-conduction threshold and the left unmasked bone-conduction threshold (reflecting right-ear response), and at 8000 Hz, where there is a 50-dB difference between the left and right air-conduction thresholds. At 1000 Hz, the masked air-conduction threshold is established for the right ear while masking noise is introduced into the left ear. At 2000 Hz, the masked air-conduction threshold is established for the left ear while masking noise is introduced into the right ear and for the right ear while masking noise is introduced to the left ear. At 4000 Hz, the masked air-conduction threshold is established for the left ear while masking noise is introduced into the right ear. At 8000 Hz, the masked air-conduction threshold is established for the right ear with masking noise in the left ear.

At 4000 Hz, if the decision to obtain the masked air-conduction threshold had been based on the unmasked rather than masked bone-conduction threshold, the masked air-conduction threshold would have been obtained unnecessarily for both ears. Note that the masked left bone-conduction threshold of 40 dB HL made it unnecessary to obtain the right masked air-conduction threshold. At 1000 Hz, if the decision to obtain the masked air-conduction threshold had been based on the unmasked rather than the masked bone-conduction threshold, the masked air-conduction threshold would have been obtained unnecessarily for both ears. Note that the masked right bone-conduction threshold of 25 dB HL made it unnecessary to obtain the left masked air-conduction threshold.

3. SPEECH-RECOGNITION THRESHOLD

The masked speech-recognition threshold (SRT) is needed if the SRT of the test ear exceeds the bone-conduction threshold of the nontest ear by at least 40 dB at any frequency. Martin (1986), based on the research by Martin and Blythe (1977) and the recommendations made by ASHA (1979), recommended that the SRT of
the test ear be compared with the bone-conduction thresholds only at 500, 1000, and 2000 Hz. Goldstein and Newman (1985) recommend that the SRT of the test ear be compared with the bone-conduction or air-conduction pure-tone average or SRT of the nontest ear. It is our experience that, although the 500, 1000, and 2000 Hz are the most important for hearing phonic words, the other frequencies can also be responsible for the recognition of phonic words, so the SRT should be compared with the bone-conduction and air-conduction thresholds at each frequency.

Our experience with the Veterans Administration population (the majority of whom have sharply sloping sensorineural hearing loss) shows that, in a considerable number of cases, the SRT is in agreement with the hearing threshold level at any single frequency between 250 and 8000 Hz; there was good intratest and intertest reliability for these findings over the years. Although many investigators (Goldstein & Newman, 1985; Konkle & Berry, 1983) employ 45 dB as the interaural attenuation for speech, we confirm Martin's (1986) recommendation for setting the interaural attenuation for speech presented by air conduction at 40 dB.

C. OCCLUSION EFFECT

The occlusion effect is the improvement in the bone-conduction threshold when the external ear is covered by an earphone (as is the case when obtaining the masked bone-conduction threshold) or when the ear canal is occluded by a finger, ear insert, earmold, or ear protector over the bone-conduction threshold when the ear canal is unoccluded (during unmasked bone-conduction testing) (Studebaker, 1979). The occlusion effect occurs primarily at the low frequencies and is, on average, approximately 2 dB at 250 Hz, 15 dB at 500 Hz, 5 dB at 1000 Hz, and 0 dB at 2000 Hz and above (Goldstein & Hayes, 1965; Martin, Butler, & Burns, 1974).

Under the unmasked bone-conduction testing condition, some of the sound generated in the ear canal by vibration of the bony part of the external auditory meatus leaves the ear through the external auditory meatus. When the external auditory meatus is occluded, the sound generated in the external auditory meatus is prevented from leaving the ear canal, so the sound-pressure level rises at the tympanic membrane. The occlusion effect does not reflect an improved hearing sensitivity by bone conduction. Rather it reflects an increase in the total energy delivered to the cochlea. (For further details on the occlusion effect, see Section III,A,3.) The occlusion effect is present in normal-hearing and sensorineural-hearing-impaired ears but not in conductive-hearing-impaired ears.

Several investigators (Goldstein & Newman, 1985; Studebaker, 1979) employ a fixed number for the occlusion effect based on the average occlusion-effect values reported in the literature. Following Martin (1986), we recommend calculating the patient's individual occlusion effect by subtracting the bone-conduction threshold just prior to masking for bone conduction (with the earphone covering the nontest ear) from the bone-conduction threshold when the ear canal is not covered by an earphone.
D. EFFECTIVE MASKING

The effective masking level (EML) is the intensity in dB HL of a signal or threshold (maskee) that a masker will just mask and the minimum effective masking (MEM) is the amount of masking noise in dB beyond the effective masking level.

For example, if the hearing threshold level at 500 Hz is 50 dB, and this threshold is just masked (i.e., the air-conduction and bone-conduction thresholds are shifted by 5 dB) by a masker of 65 dB HL, the EML is 50 dB HL and the MEM is 15 dB (65 dB HL - 50 dB HL).

Although most audiometers are calibrated in MEM, we recommend that each clinic establish its own MEM on a group of 10 normal-hearing young adults. The MEM should include a 10-15 dB safety factor. Recall from Chapter 1 that the manufacturers calibrate the audiometer masking noises in MEM based on computation with the critical band data. The behavioral procedure for establishing MEM is also described in Chapter 1.

E. INITIAL MASKING

The minimum amount of noise in dB HL required to shift the air-conduction and bone-conduction threshold by 5 dB in the nontest ear is the initial masking (Martin, 1986). Initial masking is equivalent to EML plus MEM (which has a built-in safety factor).

1. BONE CONDUCTION

Several formulas have been suggested for deriving the initial masking (IM) when obtaining the masked bone-conduction threshold. For example, Liden, Nilsson, and Anderson (1959b) proposed this formula for IM:

\[ IM = B_t + (A_m - B_m) \]

where \( B_t \) is the bone-conduction threshold in the test ear, \( A_m \) is the air-conduction threshold in the masked ear, and \( B_m \) is the bone-conduction threshold in the masked ear (assuming the dial is calibrated in effective masking).

Goldstein and Newman (1985), based on Beedle's (1971) finding, employed the following formula for IM:

\[ IM = A_{nt} + OE + 15 \text{ dB MEM} \]

where \( A_{nt} \) is the air-conduction threshold of the nontest ear, OE is the occlusion effect, and MEM is minimum effective masking. Martin (1986) recommends this formula for obtaining IM:

\[ IM = A_{nt} + \text{MEM} + OE \]

where \( A_{nt} \) is the air-conduction threshold of the nontest ear, MEM is minimum effective masking for bone conduction, and OE is the occlusion effect. The MEM is established based on the calibration of narrow-band noise in units of effective masking on a group of normal-hearing subjects.

The formula used by Liden et al. (1959b) involves subtraction so it involves lengthy computation at each frequency. The formula used by Goldstein and Newman is essentially the same as the one used by Martin (1986) except that the former assigned a fixed
number for MEM whereas the latter derived the MEM based on calibration of the narrow-band noise from the particular audiometer on a group of normal-hearing persons.

We recommend the formula for IM described by Martin (1986).

2. AIR CONDUCTION

We recommend the following formula for deriving IM when obtaining the masked air-conduction threshold based on Martin (1986):

\[ IM = Ant + MEM \]

where Ant is the air-conduction threshold of the nontest (masked) ear and MEM is the minimum effective masking for air-conduction testing. The introduction of IM to the masked ear will shift the air-conduction and bone-conduction thresholds in that ear by 5 dB.

3. SPEECH-RECOGNITION THRESHOLD

Following Martin (1986), the IM when obtaining the masked SRT can be derived from the following formula:

\[ IM = SRTnt + MEM \]

where SRTnt is the speech-recognition threshold of the nontest (masked) ear and MEM is the minimum effective masking for speech-recognition threshold testing.

F. OVERMASKING

Overmasking occurs when the masking noise crosses from the nontest to the test ear and shifts the air-conduction and bone-conduction threshold in the test ear by at least 5 dB. Similar to the mechanism for crossover of the test signal from the test ear to the nontest ear in air conduction, the crossover of the masking noise from the nontest ear to the test ear during overmasking occurs by bone conduction. That is, the masking noise, presented by air conduction, has an interaural attenuation of approximately 40 dB during crossover from the nontest to the test ear. Crosshearing of the masking noise does not necessarily result in overmasking unless the masker is sufficient in intensity to shift the air-conduction and bone-conduction threshold in the test ear by at least 5 dB.

According to Martin (1986), overmasking (OM) during bone-conduction, air-conduction, and speech-recognition threshold testing may occur when the masker intensity in the nontest ear is greater than or equal to the bone-conduction threshold of the test ear plus the interaural attenuation for air conduction (40 dB). That is, OM may occur if \( MLnt > Bt + IA \), where \( Bt \) is the bone-conduction threshold of the test ear, IA is the interaural attenuation for air conduction, and \( MLnt \) is the intensity of the masking noise in the nontest ear in dB HL. Overmasking actually does not occur until the masker intensity in the nontest ear is greater than or equal to the bone-conduction threshold of the test ear plus 40 dB plus MEM.

It is accepted clinical practice, however, not to consider the MEM when determining whether overmasking is occurring because it is desirable to be
conservative when determining whether over
masking IS OCCURRING.

G. MAXIMUM MASKING

The maximum amount of masking noise that one can introduce into the nontest ear without resulting in overmasking of the test ear is called maximum masking (MM). Maximum masking is the amount of masking noise in dB HL which is just insufficient to result in overmasking of the test ear. The formula for determining maximum masking during bone-conduction, air-conduction, and speech-recognition testing is:

$$MM = Bt + IA - 5 \text{ dB}$$

where $Bt$ is the bone-conduction threshold of the test ear and $IA$ is the interaural attenuation for air conduction (40 dB).

H. CENTRAL MASKING

The introduction of a masker into the nontest ear can result in a threshold shift even when the masker intensity is insufficient to result in overmasking. Central masking occurs because the two ears are not completely independent neurologically. The most rostral, shared neural pathways usually available to the test ear are occupied by the masker (Ward, 1963). Liden, Nilsson, and Anderson (1959b) suggested that the central-masking effect is probably mediated by the efferent pathways. Although Zwislocki (1953) reported that the central-masking effect did not exceed 5 dB, Liden et al. (1959b) found that the central-masking effect was as large as 15 dB. Several investigators (Dirks, 1964; Dirks & Malmquist, 1964; Martin & DiGiovanni, 1979; Studebaker, 1962b) have observed that the central-masking effect increases as the intensity of the masker increases. We have observed that, when the masking noise in the test ear is interrupted and the patient is re-instructed to ignore the masking and respond to the test signal, the threshold shift seen when the masking noise is initially introduced to the nontest ear is often eliminated, especially in elderly persons. Since this phenomenon occurs only in some patients, it may not be related to the central-masking effect. Nevertheless, this finding on the elimination of the threshold shift by interrupting the masking noise and re-instructing the patient suggests that further research is necessary on the nature of the central-masking effect.

I. TECHNIQUE FOR CLINICAL MASKING

Whenever masking is needed for bone conduction, the bone-conduction threshold should be re-established with the earphone on the nontest ear in order to determine the magnitude of the occlusion effect. Then the IM using narrow-band noise should be introduced into the nontest ear. With the masker in the nontest ear, the bone-conduction threshold should again be established.

If there is no shift in the bone-conduction threshold in comparison with the bone-conduction threshold in the uncovered-ear condition (unmasked), the masking procedure is terminated and this threshold is considered the masked bone-conduction threshold for the test ear. If there is an increase in the bone-conduction threshold with the introduction of IM to the nontest ear (in
comparison with the bone-conduction threshold in the uncovered-ear condition), the following plateau procedure should be employed.

After re-establishing the bone-conduction threshold upon introduction of IM in the nontest ear, increase the masker intensity by 5 dB and determine if the patient still hears the test signal. Suppose, for example, that a patient has an unmasked bone-conduction threshold of 25 dB HL, a masker of 30 dB HL is presented to the nontest ear, and the bone-conduction threshold with the IM in the nontest ear is 35 dB HL (threshold shift). The masker intensity is then increased to 35 dB HL and the clinician determines whether the patient hears the bone-conducted signal of 35 dB HL. If the patient still hears the bone-conducted signal at 35 dB HL, the masker is again increased by 5 dB to 40 dB HL and the clinician again determines whether the patient hears the bone-conducted signal of 35 dB HL. If the patient still hears the bone-conducted signal at 35 DB HL, the masker is again increased by 5 dB to 45 dB HL and the clinician once again determines whether the patient hears the bone-conducted signal of 35 dB HL. If the patient hears the bone-conducted signal at 35 dB HL, the plateau procedure is terminated and the masked bone-conduction threshold is 35 dB HL for this patient. Thus, the plateau procedure involves the introduction of IM to the nontest ear and re-establishment of the bone-conduction threshold with the IM in the nontest ear. If there is an increase in the bone-conduction threshold, the masking noise is increased by 5 dB. If the patient continues to hear the bone-conducted signal at the same intensity, the noise is again increased by 5 dB and if the patient continues to hear the bone-conducted signal at the same intensity, that intensity is taken as the masked bone-conduction threshold.

If, at any time, the patient fails to hear the test signal when the masking noise is increased by 5 dB, the intensity of the test signal must be increased in 5-dB steps until the patient responds. Then the plateau procedure is once again employed, until three or four 5-dB masking increments do not change the threshold of the test signal.

The plateau principle developed by Hood (1960) actually involved increasing the masker intensity and test intensity in 10-dB steps. A common clinical practice in masking is to use a plateau procedure involving 10-dB increments in the masking noise but only 5-dB increments in the test signal. This practice may be theoretically feasible when broadband rather than narrow-band noise close to the critical band is used.

Since most audiometers are calibrated in effective masking, it is advisable to use the same increment size for both the test signal and masker level. We recommend that the increment size be 5 dB since the clinical procedure for threshold determination involves intensity increases in 5-dB steps. Martin (1980) contended that, although the use of 10-dB increments increases the speed of the
masking procedure, it decreases the accuracy slightly.

This technique can also be applied directly to obtaining the masked air-conduction threshold, except that the test signal is an air-conducted one. This technique can be applied to speech-recognition threshold testing but with a slight modification. In this case, the test signal is speech presented by air conduction and the masker is speech noise. Also, the patient responds by repeating the word rather than by indicating (by raising the hand) that the word is heard. Whenever masking is done, the patient should be instructed to ignore the noise and to respond only to the test signal.

J. MASKING DILEMMA

Situations can occur in which introduction of initial masking results in overmasking. Suppose, for example, a patient has the unmasked air- and bone-conduction thresholds shown in Figure 19. Assume MEM is 15 dB at 1000 Hz and the occlusion effect is 0 dB. The IM is 65 dB HL (50 dB HL + 15 dB + 0 dB). Overmasking can occur when the masker intensity in the nontest ear is greater than or equal to 40 dB HL (0 dB for the bone-conduction threshold of the test ear + 40 dB IA). Thus, in this case, the IM of 65 dB HL can result in overmasking. Therefore a threshold shift that occurs upon the introduction of IM to the nontest ear may reflect OM if the IM level is sufficient to result in OM. If no threshold shift occurs with the introduction of 65 dB HL IM into the test ear, OM did not occur and it can be assumed that, for this patient, the IA was greater than 40 dB. If the introduction of 65 dB HL of IM resulted in a threshold shift but a plateau was obtained, OM did not occur even though the masking intensity exceeded the level which may result in OM. When OM occurs, no plateau will be obtained. That is, for every increment in the masker in the nontest ear, there will be an equal shift in the threshold for the signal in the test ear. This situation is referred to as a masking dilemma because it is unknown whether the threshold shift and lack of plateau in the test ear did or did not result from OM. That is, either the masking noise crossed over and caused a shift in the threshold of the test ear or a plateau could not be reached because the maximum output level for the masking noise was reached before establishing the plateau. Masking dilemmas are commonly encountered in patients whose unmasked air- and bone-conduction thresholds reveal 40-60 dB air-bone gaps, bilaterally. If OM occurs (i.e., threshold shift in the test ear upon introduction of the masker to the nontest ear, masker intensity exceeds maximum masking level, and lack of plateau), the clinician should mark on the audiogram "CNT-masking dilemma" at that test frequency.


Sometimes a plateau is not reached when the masking noise reaches the maximum output level of the audiometer, and the initial masker intensity level is insufficient to possibly cause OM. In such cases, the clinician should use the audiometric symbol indicating that the masked threshold is greater than the test signal intensity level.
when the masking noise reached the limits of the audiometer.

In some situations, a plateau will not be reached because the threshold of the test signal is beyond the output limits of the audiometer. If OM is not a possibility, the clinician should put the symbol representing a masked threshold beyond the audiometer output limits on the audiogram. For example, suppose 40 dB IM is introduced into the nontest ear of a patient and the bone-conduction threshold with the masker in the nontest ear increases to beyond 65 dB HL (the limits of the audiometer). If the possibility of OM does not occur until the masker intensity reaches 60 dB HL (for example) for this patient, the clinician should indicate that the masked bone-conduction threshold in the test ear for this patient was greater than 65 dB HL.

Figure 19 Audiogram with the unmasked air- and bone-conduction thresholds. Masking dilemma is illustrated.

K INSERT EARPHONES

Insert earphones have been used to increase the interaural attenuation for air conduction, thereby reducing the frequency of clinical situations in which the masked bone-conduction or air-conduction threshold is needed. Furthermore, the use of insert earphones reduces the frequency of occurrence of masking dilemmas since the increased interaural attenuation for the masker means OM is less likely to occur.

According to Zwislocki (1953), the IA for air-conducted signals is inversely proportional to the surface area exposed to acoustic or mechanical force. With insert earphones, the surface area vibrated is reduced, resulting in decrease in the intensity of the air-conducted signal transmitted through the skull bones to the other cochlea (crossover involves the bone conduction route). As a result, the interaural attenuation for air conduction is increased.

The most commonly used insert earphone is the ER-3A manufactured by Etymotic Research. With deep insert earphone insertion (back surface flush with the orifice), the IA values were increased significantly over those for the TDH-39 and TDH-49 earphones, especially at the low and mid frequencies. Table XI shows the means and ranges for the IA values obtained with the ER-3A insert earphones (Sklare & Denenberg, 1987), the TDH-39 earphones (Killion, Wilber, & Gudmundsen, 1985), and TDH-49 earphones (Sklare & Denenberg, 1987). As can be seen from this table, the IA for the insert earphones is as much as or greater than 100 dB below 1000 Hz. The IA values obtained with shallow insert earphone placement (back surface of the plug is slightly lateral to the orifice of the ear canal) is less than those for deep-insert earphone insertion.

### Table XI Mean Interaural Attenuation Values in dB and Ranges for the Deeply Inserted ER-3A, Supra-Aural TDH-39 Earphones, and Supra-Aural TDH-49P Earphones

<table>
<thead>
<tr>
<th>Transducer</th>
<th>Frequency [Hz]</th>
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Figure 20  Interaural attenuation obtained on subject ER with deep earplug insertion in both ears (■), with shallow insertion in deaf ear only (▲), and with shallow insertion in both ears (●). Reprinted with permission from Killian, Wilber, and Gudmundsen (1985).

Figure 20 shows the IA values obtained in a patient with deep earphone insertion in both ears, shallow insertion in the hearing-loss ear only, and shallow insertion bilaterally.

AUDIOMETRIC WORKSHEETS

ATTACHED ARE 15 COPIES OF
AUDIOMETRIC WORKSHEETS TO BE USED
IN CONJUNCTION WITH LABORATORY ASSIGNMENTS
AND CLASS DEMONSTRATIONS
AUDIOMETRIC WORKSHEET

**NAME ____________________ DATE OF BIRTH ____________ DATE OF TEST ____________**

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**AUDIOMETRIC SYMBOLS**

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- Air Conduction Unmasked
- Air Conduction Masked
- Bone Conduction - Mastoid Unspecified
- Bone Conduction - Mastoid Unmasked
- Bone Conduction - Mastoid Masked

**Effective Masking Levels to Non-Test Ear**

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AUDIOMETRIC WORKSHEET

NAME _____________________ DATE OF BIRTH ____________ DATE OF TEST ____________

AUDIOMETRIC SYMBOLS

- Air Conduction
- Unmasked
- Masked
- Bone Conduction - Mastoid
- Unspecified
- Hearing Level in Decibels (dB)

Effective Masking Levels to Non-Test Ear

Student Name _____________________ Assignment _____________________
AUDIOMETRIC WORKSHEET

Name ____________________ Date of Birth ____________ Date of Test ____________

Student Name ____________________
Assignment _______________________

AUDIOMETRIC SYMBOLS

- Air Conduction
- Unmasked
- Masked
- Bone Conduction - Mastoid
- Unspecified
- Unmasked
- Masked

Effective Masking Levels to Non-Test Ear
AUDIOMETRIC WORKSHEET

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AUDIOMETRIC SYMBOLS

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Effective Masking Levels to Non-Test Ear

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### AUDIOMETRIC WORKSHEET

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### AUDIOMETRIC SYMBOLS

- **Air Conduction**
  - Left Ear: X
  - Right Ear: ○
- **Bone Conduction - Mastoid**
  - Left Ear: △
- **Unspecified**
  - Left Ear: >
  - Right Ear: <

### Effective Masking Levels to Non-Test Ear

- **AC**
  - RE: [ ]
  - LE: [ ]
- **BC**
  - RE: [ ]
  - LE: [ ]
### AUDIOMETRIC WORKSHEET

**NAME ____________________ DATE OF BIRTH ____________ DATE OF TEST ____________**

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**AUDIOMETRIC SYMBOLS**

- **Air Conduction**
  - Left Ear: X
  - Right Ear: O
- **Bone Conduction - Mastoid**
  - Left Ear: △
- **Unspecified**
  - Left Ear: >
  - Right Ear: <

**Effective Masking Levels to Non-Test Ear**

- **Left Ear (LE)**
  - AC: [ ]
  - BC: [ ]
- **Right Ear (RE)**
  - AC: [ ]
  - BC: [ ]
**AUDIOMETRIC WORKSHEET**

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**AUDIOMETRIC SYMBOLS**

- **Air Conduction**
  - Left Ear (X)
  - Right Ear (O)

- **Bone Conduction - Mastoid**
  - Unspecified (Δ)
  - Unmasked (>)
  - Masked (<)

**Effective Masking Levels to Non-Test Ear**

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AUDIOMETRIC WORKSHEET

NAME ____________________ DATE OF BIRTH ____________ DATE OF TEST ____________

Student Name____________________
Assignment____________________

AUDIOMETRIC SYMBOLS

- Air Conduction
- Unmasked
- Masked
- Bone Conduction - Mastoid
- Unspecified
- Unmasked
- Masked

Effective Masking Levels to Non-Test Ear

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Effective Masking Levels to Non-Test Ear

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AUDIOMETRIC WORKSHEET

Student Name_____________________
Assignment_____________________

NAME __________________ DATE OF BIRTH ____________ DATE OF TEST ____________

AUDIOMETRIC SYMBOLS

Air Conduction
Unmasked
Masked
Bone Conduction - Mastoid
Unspecified
Unmasked
Masked

Effective Masking Levels to Non-Test Ear

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AUDIOMETRIC SYMBOLS

- Left Ear: X
- Right Ear: O
- Unmasked: □
- Masked: △

Effective Masking Levels to Non-Test Ear

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**AUDIOMETRIC WORKSHEET**

**NAME _____________________ DATE OF BIRTH ____________ DATE OF TEST ____________**

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**AUDIOMETRIC SYMBOLS**

- **Air Conduction - Left Ear**
  - Unmasked: X
  - Masked: O
- **Bone Conduction - Mastoid - Left Ear**
  - Unspecified: □
  - Unmasked: >
  - Masked: <

**Effective Masking Levels to Non-Test Ear**

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TERM PAPER COVER SHEET
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Student Name: ________________________________
(Also fill out the back side of this sheet)

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<td>The topic is a current and significant to the field of audiology.</td>
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<td>Depth of content</td>
<td>The topic is treated in depth and focused.</td>
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<td>Clarity of writing</td>
<td>Correct terminology and concepts are used that are common to professional writing in audiology. Professional language is used.</td>
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<tr>
<td>Quality of content</td>
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<td>Show a good review of the topic in scholarly papers and journals.</td>
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Course: ________________________________

Date: ________________________________