AUDI 560: Audiologic Assessment II

**Historical Perspectives**

“If you would not be forgotten,
As soon as you are dead and rotten,
Either write things worthy of reading,
Or do things worth the writing”

Benjamin Franklin (1706-1790)
Then & Now

1948: Diagnostic test battery:
- Tuning fork tests
- PTA
- SRT
- SDS – Monosyllabic words
- Traditional site of lesion tests

2001: Diagnostic test battery:
- PTA + High frequency
- SRT
- WRS – Speech perception tests – variety of materials
- Immittance - Reflectance
- ERA – Imaging technologies
- OAE
- ENG - Posturography
Chronological Summary of Major Advances in Site of Lesion Testing

- 1834: Tuning fork tests - Weber
- 1893: Rudimentary tone decay tests – Gradenigo & Allen
- 1930: Audiometer (Western Electric)
- 1935: Monaural loudness balance (MLB) – Reger
- 1937: Alternate binaural loudness balance (ABLB) - Fowler
- 1946: Impedance audiometry – Metz
- 1947: Bekesy audiometer – Bekesy
- 1948: ABLB in site of lesion evaluation – Dix, Hallpike, & Hood
- 1948: Difference limen for intensity: Luscher & Zwislocki
- 1957: Tone decay – Carhart
- 1959: Short increment sensitivity index (SISI) – Jerger, Shedd, & Harford
- 1960: Bekesy threshold types – Jerger
- 1969: Acoustic reflex decay – Anderson, Barr, & Wedenberg
- 1972: Bekesy forward-backward – Jerger, Jerger & Mauldin
- 1974: Tone decay – Olsen & Noffsinger
- 1974: Bekesy comfortable loudness (BCL) – Jerger & Jerger
- 1975: Suprathreshold adaptation test (STAT) – Jerger & Jerger
- 1978: Clinical OAE – Kemp (theoretical OAE – Gold, 1940s)
- 1993: Wide band reflectance – Keefe & Colleagues
Rise & Fall of The Traditional Site of Lesion Diagnostic Tests

- ABLB
- SISI
- Tone Decay Tests
- Bekesy
- PIPB
ABLB

- Background information
  - Compares loudness growth in an impaired ear versus a normal hearing ear
  - Discovery of abnormal loudness growth in cochlear pathology: Roger, 1935 and Fowler 1936 & 1937
  - Application of ABLB as site of lesion test: Dix, Hallpike, & Hood, 1948
General Principles

- Test of recruitment
- Is for unilateral SNHL
- Compare the loudness growth between the same frequency for the two ears
- The intensity that is required to produce equal loudness is much less for the impaired ear than the normal ear
Test Administration

- Test is performed by alternating a fixed frequency between the two ears, keeping the intensity in the good ear constant while varying the intensity in the impaired ear.
- The client's task is to state whether the signal is “softer than,” “louder than” or “equal” in loudness to the reference (normal/good) ear.
- Test begins at 20 dB SL in the reference (normal/good) ear.
- After equal loudness is judged, the intensity is increased in 20 dB steps until either the patient’s tolerance level or the maximum output of the audiometer is reached.
ABLB – Test Interpretation

A. Complete recruitment: When reference and variable ears are judged equally loud at equal HLs ±10 dB

B. No recruitment: If equal loudness judgments are made at equal SLs ±10 dB
C. **Partial recruitment**: If equal loudness judgments fall between those of complete and no recruitment.

D. **Decruitment**: The poor ear needs an ever increasing amount of intensity for a signal to sound equally loud to the good ear. In this case the SL difference is 15 dB or more in the poor ear than in the good ear.
ABLB

- **Advantages**
  - Effective test of recruitment
  - Effective in detecting cochlear disorder
  - Easy and quick to administer

- **Disadvantages**
  - Cannot be administered in cases of bilateral hearing loss
  - Less effective in detecting retrocochlear pathology
  - Comparison of loudness at low intensity level in the normal ear versus loudness at a relatively high intensity level in the impaired ear (a function of stimulus level not a cochlear pathology – Sanders 1982)
SISI

- **Background information**
  - Refers to the ear’s ability to discriminate changes in intensity.
  - Difference limen for SISI is defined as the increment in the physical intensity of a sound which a subject perceives as a change in loudness just 50 percent of the time.
  - Evolved from Fowler’s description of loudness recruitment (1936 & 1937).
  - Named SISI by Jerger (1952) while he was summarizing a Master’s thesis under the direction of Raymond Carhart.
SISI

- Basic Principles
  - The normal ears are not as sensitive to changes in intensity when listening to low level signals. Very sensitive to intensity changes when listening to high level signals.
  - The ears with cochlear pathology are able to detect small changes in intensity at low sensation levels.
Test Administration

- The carrier Tone is introduced into the patient’s ear at a SL of 20 dB
- Every 5 sec a short increment is superimposed, starting with 5 dB increments
- Signal has on and off time of 50 msec and 5 sec elapse between increments
SISI

- Test administration
SISI

- **Test interpretation:** One dB increments at 20 dB SL; twenty separate presentations of the 1 dB intensity increment are presented at each test frequency
  - ≥ 70% : positive for cochlear pathology
  - ≤ 30% : negative for cochlear pathology
  - 30% - 70%: not strongly diagnostic/Inconclusive
Modified SISI Test

- This test is carried out at high SLs
- Thompson (1963) administered the test at 1000 Hz using 1 dB increment at 75 dB HL in two cases of surgically confirmed acoustic neurinomas. The patient’s normal ear served as a control
- At high levels both patients were able to detect small increments (1 dB) in the normal ear but not in the affected ear
SISI

Advantages
- Easy and quick to administer

Disadvantages
- High SISI scores do not consistently rule out retrocochlear pathology. Patients with cochlear impairment do not necessarily detect small increments at low intensity levels
Tone Decay

- **Background information**
  - Tone decay is a perceived decrease in the loudness of a steady-state signal.
  - The clinical observation of tone decay (auditory adaptation) in retrocochlear pathology dates back to 1893 (Gradenigo & Allen).
  - Description of abnormal tone decay in patients with confirmed 8th nerve tumors by Reger & Kos (1952) using Bekesy audiometry.
Tone Decay

- General Principles
  - Based on auditory adaptation
  - Quantified in two ways:
    - Measure amount of tone decay in dB (subtract beginning presentation level from ending level, Rosenberg, 1958)
    - Measure “time to inaudibility” as a function of signal level (Owen, 1964)
Tone Decay

- Test administration
  - Schubert (1944) method
  - Hood (1956) method
  - Carhart (1957) method
  - Rosenberg (1958) method
  - Green Modified Tone Decay Test (MTDT) method (1960)
  - Owen (1964) method
  - Olsen & Noffsinger (1974) method
  - Jerger & Jerger Suprathreshold Adaptation Test (STAT) method (1975)
Tone Decay Test

**Rosenberg Method**

- Obtain the subject’s threshold of hearing for an interrupted tone
- Instruct the subject to raise his finger as long as he hears the tone and to lower it if the signal fades into inaudibility
- Begin the test with a sustained tone at 5 dB SL
- Begin the timing with a stop watch. If the tone is heard for a full minute, stop the test
- If the subject indicates that he no longer hears the tone before the minute is completed, raise the intensity of the tone by 5 dB without interrupting the stimulus and without stopping the watch
- Continue in like manner raising the tone in 5 dB steps each time the tone becomes inaudible. At the end of 60 sec, the tone is turned off and the amount of tone decay in dB is computed
Tone Decay Test

- Interpretation of test results (Rosenberg, 1958)
  - 0-5 dB: Normal
  - 10 –15 dB: Mild
  - 20 – 25 dB: Moderate
  - 30 dB or more: Marked

Note: Mild to moderate levels of tone decay were frequently seen in pathology involving organ of corti, whereas marked tone decay almost always indicated retrocochlear pathology (Rosenberg, 1969)
Tone Decay – STAT Method

- **Test administration**
  - The patient is instructed to signal as long as he hears the sound in the test ear. The nontest ear is masked with white noise at a level of 90 dB SPL.
  - A continuous 500 Hz test tone at 110 dB SPL is presented until either the patient indicates that he no longer hears the tone, or until 60 sec have lapsed, which ever comes first.
  - The test is scored positive if the patient has failed to respond for the full 60 sec.
  - The test may continue for 1000 Hz and 2000 Hz.
Tone Decay

- Advantages
  - Low cost and general accessibility

- Disadvantages
  - Pathophysiologic essence of tone decay is not very well known
  - The actual value of any tone decay procedure in accurately identifying 8th nerve pathology has not been extensively investigated (the literature on ABLB and SIS is subject to same criticism)
Bekesy

- **Background information**
  - Bekesy developed the first automatic audiometer (1947)
  - Jerger (1960) delineated four distinct Bekesy tracings; fifth was added later
Bekesy

- General principles
  - Bekesy automatic audiometers allows for both threshold assessment and site of lesion testing
  - Two modes of pure tone presentation:
    - Continuous tone (C)
    - Interrupted tone (I)
  - Two tracing modes:
    - Sweep frequency (SF): frequency continually changes from 100 – 10,000 Hz or the reverse (samples tone at a rate of one octave per min.)
    - The fixed frequency (FF): allows any one of a number of frequencies to be assessed individually (traced for I and then C tone at an attenuation rate of 2.5 dB /Sec)
Test administration

- Patient is instructed to activate the intensity switch when the test tone is just heard and release the switch immediately when the test signal becomes inaudible
- The audiometer automatically increases intensity 2.5 dB/sec – when the patient releases the switch
- Important tracing features
  - Threshold
  - Width (refers to the peak-to-trough range in dB)
  - Separation ( separation between the I and C tracings)
Bekesy - Interpretation

- **Type I**: SF is characterized by an overlapping of I & C tracings with a tracing width of about 10 dB – It is found in normal, CHL, and SNHL of unknown etiology

- **Type II**: The C tracing falls below I, generally at or above 1000 Hz (not more than 20 dB) Usually seen in SNHL with cochlear origin. It is strictly cochlear pattern

- **Type III**: Dramatic drop of the C below the I with a separation of 40 – 50 dB or higher. Consistent with retrocochlear pathology.

- **Type IV**: C dropping below the I at frequencies lower than 1000 Hz as opposed to the type II. Could be cochlear or retrocochlear.
Bekesy - Interpretation

- Type V: I drops below the C indicative of pseudohypacusis
Bekesy Comfortable Loudness (BCL)

- Developed in an effort to increase sensitivity for retrocochlear pathologies
- Bekesy audiograms are traced at suprathreshold levels rather than threshold levels
- Patient is instructed to press the button when the signal is just uncomfortably loud and to release the button when the signal is just less than comfortably loud
- The patient is also instructed that he will hear a continuous noise (masking) in the nontest ear
N1, N2, N3 patterns show no unusual adaptation for C vs. I tracings. This outcome is consistent with normal, conductive, mixed, and cochlear auditory pathology.
BCL Interpretation

- P1, P2, P3 patterns show unusual adaptation for the C compared to the I tracing. This outcome is consistent with retrocochlear pathology.
PI Function

- The Shape of the PI function is unique and depends on:
  - Patient and speaker
  - Type of pathology
  - Type of material
- The maximum performance (Phonetically balanced - PB Max) can be obtained from PI function
PI Function & Test Materials

1. Synthetic sentences, Speaks
2. NU6M, Tillman
3. NU6F, Tillman
4. CID W-22, Hirsh
5. NU6, Wilson, et al.
6. Harvard PB 50, Egan,
PB Max

80% obtained at 20 dB HL
Highest score of 100% reached at 30 dB HL (PBmax = 100%)

50% inferred at 14 dB HL

30% obtained at 10 dB HL

0% obtained at 0 dB HL
PB Max and PI & Site of Lesion

a. Normal PI
b. CHL PI
c. SNHL PI
d. SNHL PI
e. Retrocochlear PI
PL for Differential Diagnosis

- PB max can be found by obtaining PI function at discrete 10 dB steps from 10-20 dB SL re SRT, however, it may not be feasible if time is an issue.

- PB Max obtained at one level, 80 dB HL provided this level is not < SRT + 30
  - If PB Max at this level is =>84% further testing to obtain PB Max is not necessary
    - Reason: Even if the max score of 100% was obtained at a lower or higher intensity level, the difference score of 16% (PB max – PB min) is less than the 20% criterion difference to be considered rollover (Jerger & Jerger, 1971)

- If score is < 84 %
  - Higher PL is needed to achieve PB max because of reduced audibility
  - Lower PL is needed because the score reflects rollover
PIPB Function

Rollover Index (RI):
RI = (PB max - PB min) / PB max
RI = (64-38)/64
RI = 26/64 = 0.41

For NU6 the cut off value is > 0.25 (Bess et al., 1979)
or > 0.35 (Meyer & Mishler, 1985)
PIPB Function