SPAU 426

Clinical Practicum in Audiology II

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Introduction to Auditory Brainstem Responses

Principles of evoked potentials

- It is possible to measure electrical activity associated with peripheral or central neural activity
- Variation in electrical activity = voltage change
- Response linked to stimulus

Neurophysiological basis of evoked potentials

- Neuro-electric field generated by **nerve action** potentials
- **Synchronization** of large number of neural responses
- Change in **electrical potential** over time
- The **smaller** or more diffuse the potential, the **nearer** the measurement system must be: Far-field vs. Near-field recording

Parameters of clinical interest

- Magnitude (amplitude)
- Latency
- Present or not

Magnitude of the response

Magnitude=amplitude=voltage

Peaks in amplitude are associated with **synchronous** neural activity

e.g. brainstem nuclei-“relay stations” in the lower brain

Peaks have a typical range (though often not as reliable as latency)

Latency

- Latency -timefrom stimulus presentation, usually measured in ms
- Later-more central, **earlier**-more **peripheral**
- Expected latency determines time window of measurement
- Different evoked potential measurements are subdivided by latency and this is linked to generator site/origin

Measurement parameters

Use	Use appropriate, calibrated stimuli at suitable rate
Use	Use appropriate transducer
Record	Record the response using appropriately chosen and configured electrodes
Use	Use the appropriate time window
Optimise	Optimise signal to noise conditions

Stimulus Characteristics

- Can either use a **broadband stimulus** (e.g. a click), or a **frequency specific** stimulus
- Measuring responses at several frequencies can be time consuming
- Should use a very **brief stimulus** to get good neural **synchrony**
- Compromise is needed on desired response characteristics and measurement characteristics

Stimulus Characteristics

The type of stimulus you can use depends on the measurement you are making:

- For brainstem and other short duration responses use short duration stimuli to get synchronous firing –clicks (broadband) or tone bursts (frequency specific)
- For later responses such as slow vertex response can use speech sounds as well
- Steady state responses use amplitude modulated tones

Stimulus calibration

- Amplitude modulated tones
  - no problem (dB HL)
- Clicks or tone bursts –more involved
  - Peak equivalent SPL (dB peSPL)
  - Normal hearing level (dB nHL)
  - Individual subject sensation level (dB SL)

dB nHL(normal hearing level)

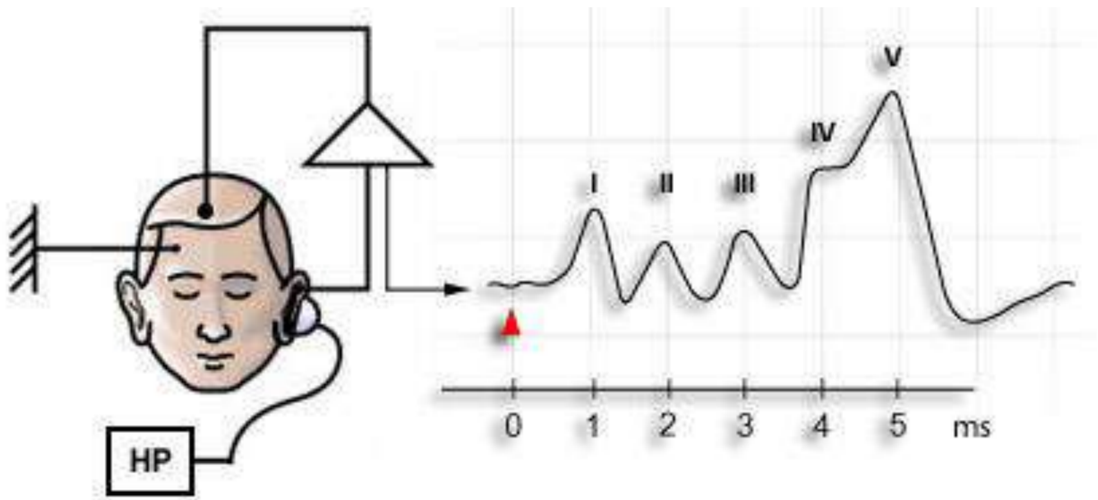
- Take a group of normal hearing subjects
- Find the average threshold of those subjects to the stimulus (e.g. the threshold on an arbitrary dial setting)
- Define that dial setting as 0 nHL
- 40 dB nHL is when the stimulus is 40 dB louder than the 0 nHL setting

Signal to noise problem

- The problem: the signal of interest is between 0.5 and 50 microvolts; the noise (EEG/EMG interference) is at least 50 microvolts

- **Sources of “noise”:**
  - Physiological: Spontaneous EEG, muscle potentials, cardiac potentials, electro-ocular potentials, electrodermalpotentials
  - Non-physiological: electromagnetic, electrostatic, instrumentation noise

- **The ABR: Measured using surface/scalp electrodes. Recorded as 5 main waves of electrical activity from**



Cochlear changes sound into action potentials (coded for frequency, intensity and timing information)

Cochlear division of CN VIII carries this information to the brain

Undergoes processing in the B/S and thalamus before reaching the cortex

Depends on a large number of neurons to fire simultaneously

2 primary clinical applications

Depending on which application you require, you need to adjust your protocol

Applications

- Identification of **neurological abnormality** in the VIII nerve and brainstem pathway
- Estimation of **hearing sensitivity** based on the presence of a response at various intensity levels:
  - AC click
  - BC click
  - LF tone bursts

Four main nuclei at the brainstem level

Cochlear Nucleus:

- 1st synapse point after the first auditory neurons exit the IAC
- Divided into Dorsal and ventral CN
- Tonotopically organised like the cochlear

SOC:

- 2nd nucleus
- Located in lower pons (core portion)
- Involved in understanding speech in noise
- Localisation and first place of bilateral representation
- First point of decussation

Lateral Lemniscus: Not a nucleus but the largest tract of auditory fibres that carry information of the CN and SOC to the Inferior Colliculusin the midbrain

Inferior Colliculus:

- Located in the midbrain
- Tonotopical representation continues
- Also with localisation
- Communicates with Superior colliculusso that maps of visual and auditory spaces are congruent, and for co-ordination of head movement for auditory and visual stimuli

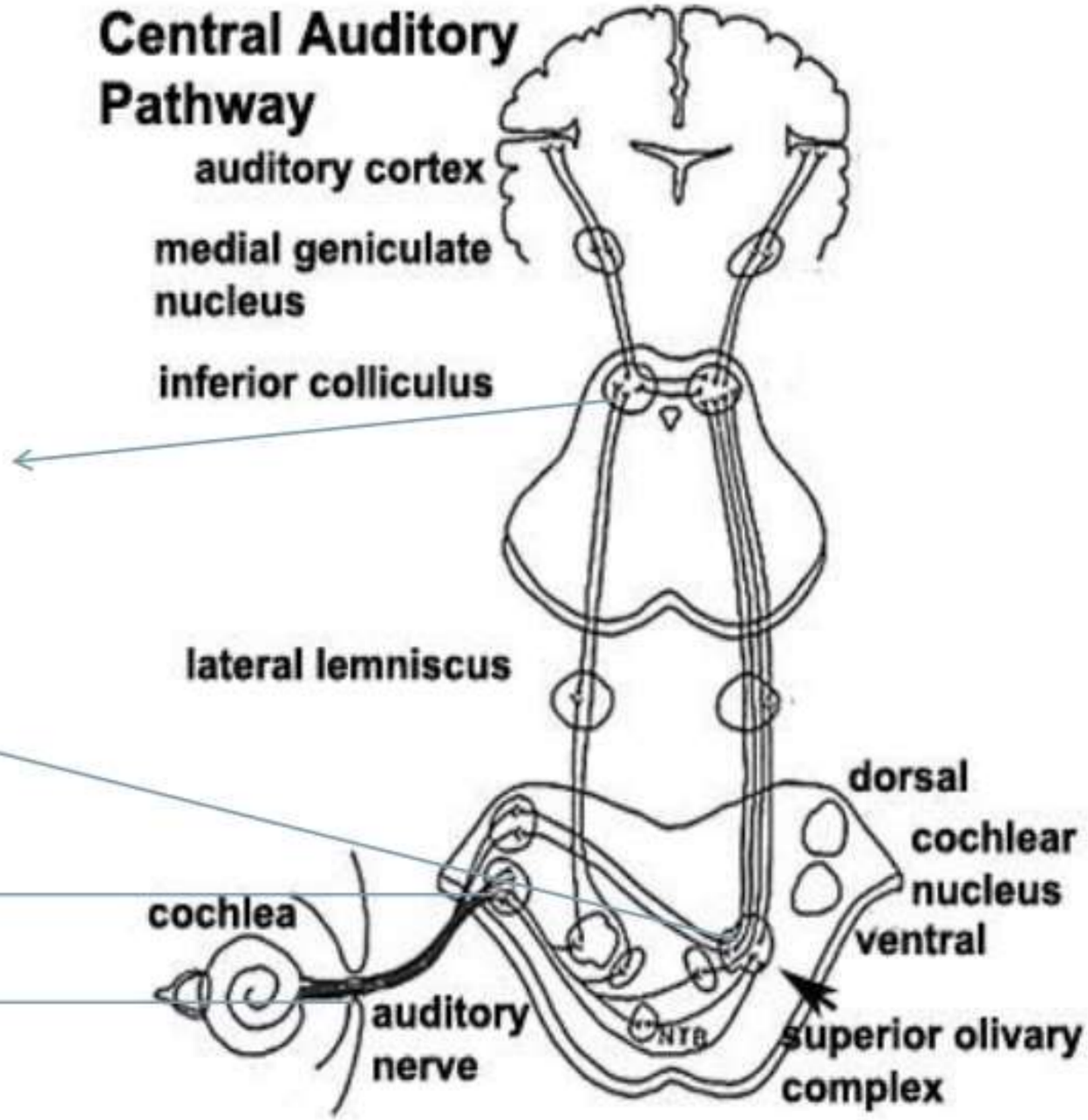
Four main nuclei at the brainstem level

Medial geniculate body:

- Located in the thalamus
- Receives input for pain, touch, auditory and visual stimuli that come from cerebellum and superior colliculus.
- Ventral division is for auditory input
- Tonotopically organised
- Receives sound information: source, location, onset, offset, freq, intensity
- Projected from here to the Primary auditory cortex (nor directly—but via a few other stops!)

Accepted sites

- IV and V
- III
- II
- I



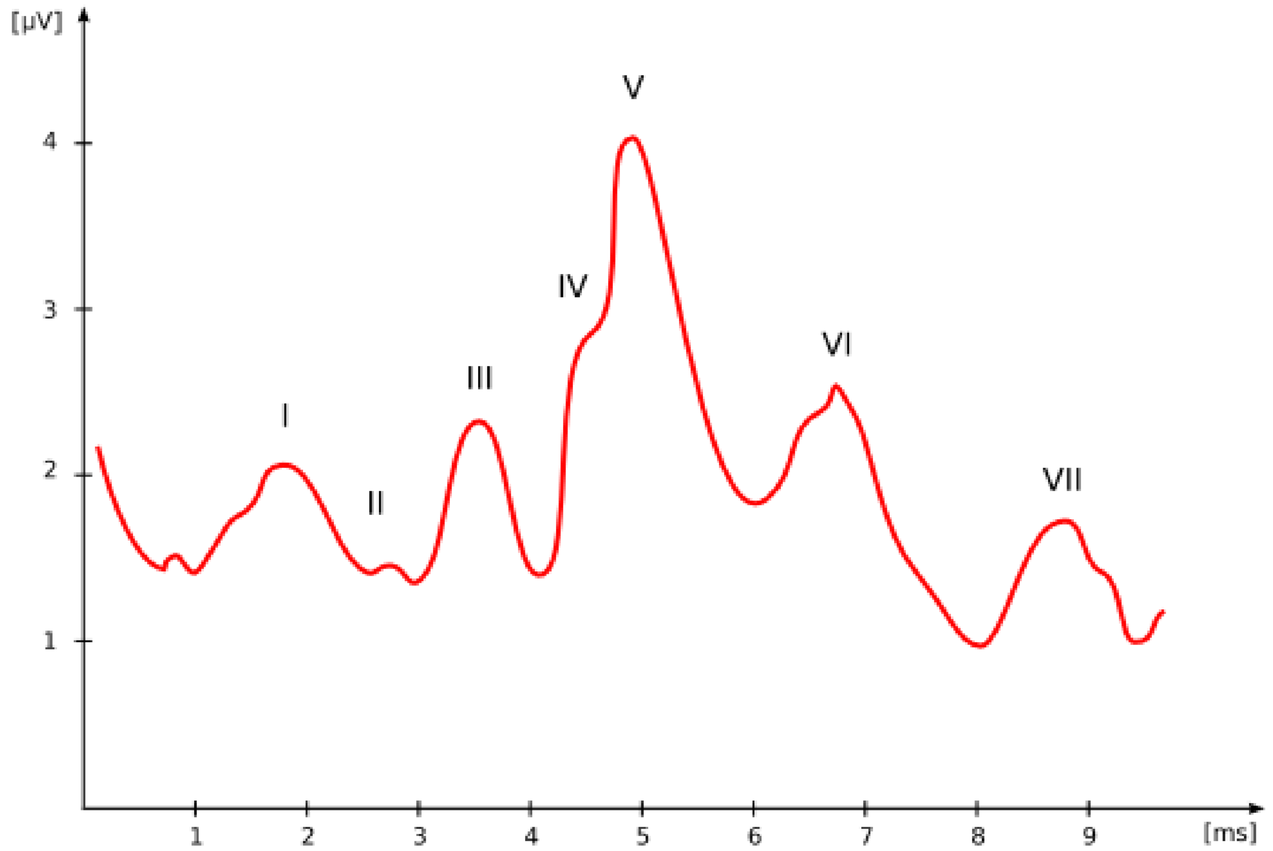
The ABR Waveform

Recordings will contain **peaks and troughs**, some more identifiable than others

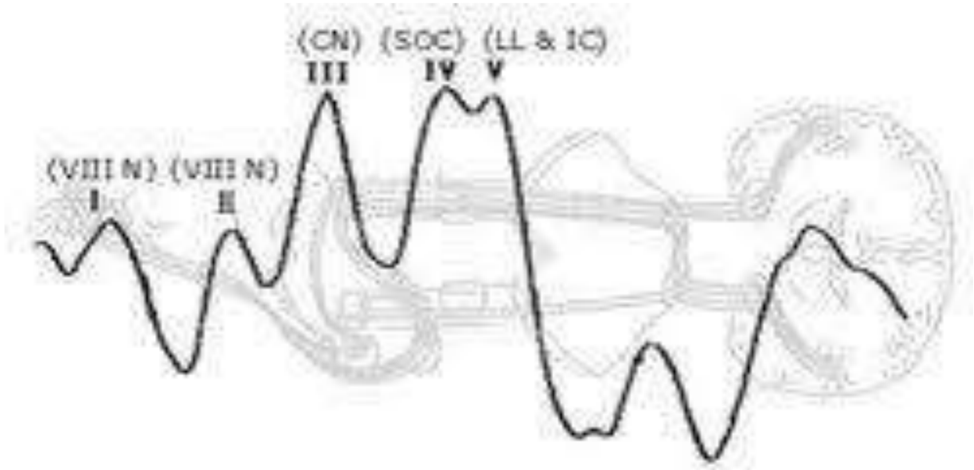
Peaks **I**, **III** and **V** are the most identifiable and most reliable clinically

(Amplitudes), latencies and relationship of the peaks can be used for differential diagnosis

Latencies



Linda Hood (1998)



ABR measure

- **Latency:** time from stimulus onset to emergence of peak or trough
- Absolute latencies of I, III and V and interpeaklatencies I-III, I-V and III-V
- **Amplitude**: Size of peak to peak measure or baseline to peak for I,III and V
- V larger than I
- IAVD

Clinical Use of the ABR

- Newborn and DTT population
- Not affected by patient's state of arousal or by the use of sedation/anaesthesia
- Does not require patient co-operation
- Intra-operative monitoring
- Assess hearing loss
- Neurologic ABR for differential diagnosis

Factors affecting the ABR

- Age
- Gender
- Stimulus-intensity, time, polarity, duration, repetition rate, masking
- Filters: bandwidth
- Recording site: electrode position

Equipment and Brief overview of procedure

Equipment and Brief overview of procedure

- Headphones or Inserts used to deliver stimulus. Also Bone conductor for BC testing
  - As always need to ensure ear canals are clear for insert use in particular
  - There is a difference when using insert vsTDH-39 so must be carefully reported.
- Electrodes
  - Used for acquiring recordings
  - Cleaning the site is essential for reliable testing, with impedance no greater than 5ohms
  - Conduction gel also applied depending on type of electrode. E.gAg/AgClor disposable already has a gel-Coupling between skin and electrode

Electrode Placement

- Inverting (-): Ipsilateral(Testing) on mastoid of test ear
- Non-inverting (+): High forehead or Cz.
- Ground: Contralateral mastoid. Required for proper functioning of the amplifier.
- ABR recorded by measuring the electrical activity between 2 electrodes

Patient Preparation

- Comfortable and quiet environment
- If asleep, sedated or under GA, all the better
- Beware of interference
- Ensure all mobiles and other equipment not required are switched off—not on silent
- Location in hospital is critical—e.g. next to MRI scanner

Test Protocol

- Will depend on what type of ABR you are doing
- Usually stored on system
- Important parameters:
  - ✓Filter bandwidth
  - ✓Stimulus type and repetition rate
  - ✓No of sweeps/averages
  - ✓EEG and amplifier: artefact rejection

Test Parameters

- Epoch: Time base or recording window. Start corresponds to start of the stimulus.10 to 20ms usually.
- Amplifier gain: Small ABR peaks, therefore electrical activity needs to be amplified.
- Stimulus type: click, tone pips, -what are you trying to achieve? Frequency specificity?
- Stimulus rate: High if you want recording time as short as possible and low if you want to maintain the characteristics of the response. 11-20/s for neuro-otoand 60/s threshold ABR

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Test Parameters

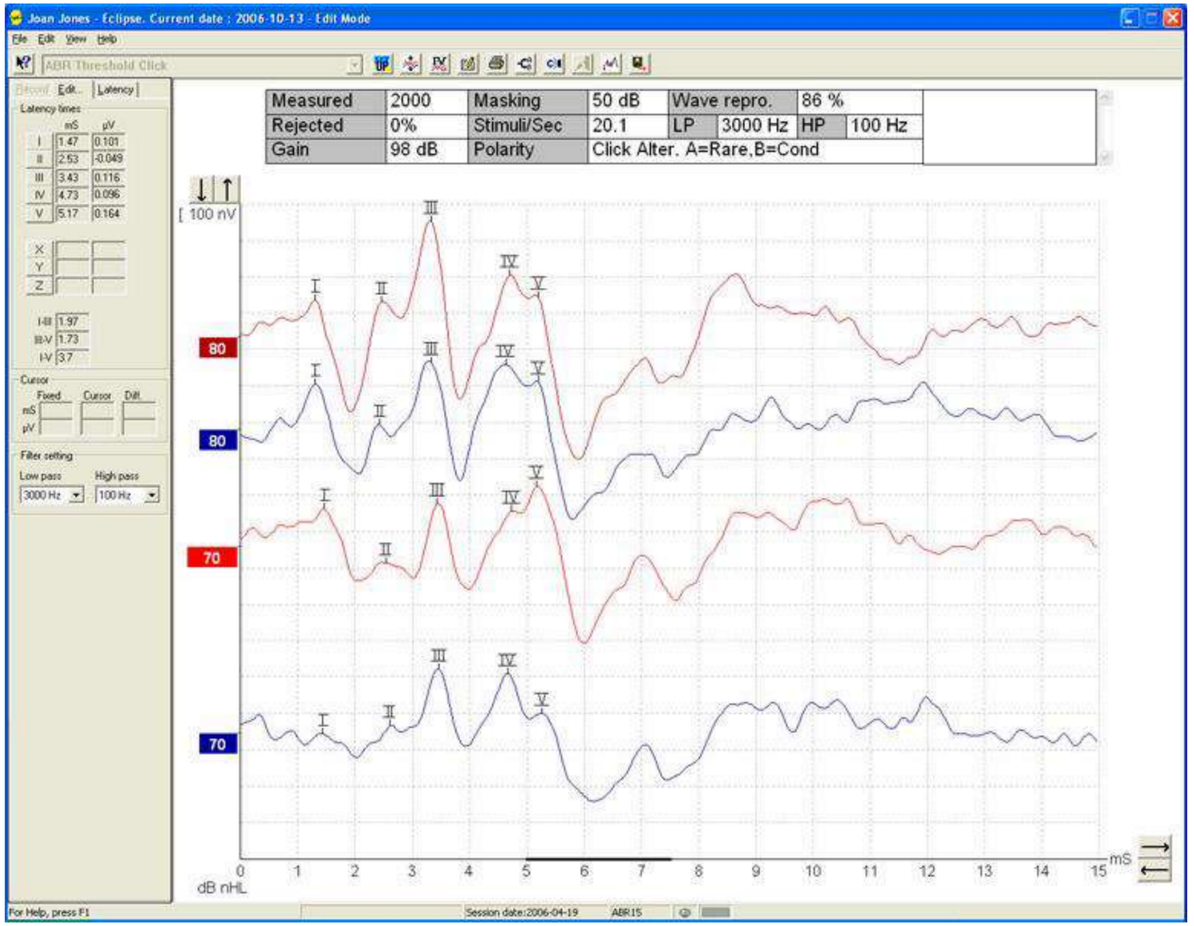
- Stimulus Intensity: Threshold vs Neuro-oto
- Polarity: relative amplitude effects on components
- No of sweeps/averaging: Improving the signal to noise ratio. ABR small response buried in the signal noise. ABR is time locked to stim onset but noise interference occurs randomly. 2000 usual.

Continued: Amplifier

- **Filter bandwidth**: removes signals out of the frequency range of interest (a low and high). 30-3000Hz provides a low frequency response-clear I and V diffs in amplitude. 300-3000Hz –flatter response with near equal amplitudes for all components. Eliminates portion of interference **(noise)**

- **Artefact rejection** (sensitivity): Set so that all low level activity collected but excessive activity rejected. Movement and excessive EEG activity. Rejection based on amplitude, can be sign. Problem when testing close to (T) and you have low amplitude responses

Results: or Waveforms



Interpretation: Neuro-otological ABR

- Useful for detection of retro-cochlear lesions, e.g. tumours on the auditory nerve, intra-axial tumours (within the brain stem), outside the B/S (extra axial)
- Demyelinating disease, e.g. MS
- Vascular Lesions of the B/S, blockage or haemmorhageof blood vessel
- Differential diagnosis of comatose patients: Metabolic or toxic cause of coma (drug overdose) vs. coma due to structural lesion)
- **Status of Auditory nerve and B/S pathways**

Neuro-otological ABR

- Damage to different areas affect the ABR in characteristic ways
- Site of lesion affects the ear in which the ABR abnormalities manifest
- In general, auditory nerve lesion: ipsilateraleffects
- Large CPA tumours, may see contralateral effects due to B/S compression
- B/S lesions may cause ipsilateral, contralateral or bilateral abnormalities of the ABR.

Procedural differences

- Not finding threshold, so wave V is threshold not needed
- Intense stimulus level needed (usually between 60 and 90dB nHL)
- Must repeat so that you have at least 2 similar waveforms before marking waves I to V

Interpretation

- IPL: I-V. : normal is about 4ms (Stockardet al, 1980)
- I-III and III-V can be obtained as well. This will help pinpoint more precisely the location of lesion
- Can also compare these between right and left sides for patient.
- IAVD—very useful when you can not elicit wave I and therefore can not measure IPLs
- Can be more sensitive than absolute wave V latency-may not fall out of normal range but when compared with other ear, should not be 0.3 to 0.4ms difference between ears

Interpretation

- Wave V/I ratio: peak to peak amplitudes of I and V.
  - In normals, ratio of V to I is >1.0uV.
- A retrocochlearpathology may result in small V, with a ratio of less than 1.0 uV. EgI=0.12uV and V=0.64uV. Ratio =5.3
- Absent waveform components- lesions at the location/ primary generator site

- Beware of **unilateral or asymmetrical hearing losses** as this may account for wave V differences
- Ensure that you have a **PTA before** doing a Neuro **ABR**, as this will help in choosing stimulus intensity and interpretation of results
- In other words, if ABR is absent when there is a severe peripheral hearing loss, you cannot use Neuro ABR as part of your Neuro-otology assessment.

Interpretation: Threshold ABR

- Wave V most robust
- Well correlated with behavioural audio thresholds
- As intensity decreases, most ABR waves disappear except V which can be elicited within 10-20 dB of behavioural threshold
- Normally begin at around 60dBnHL and continue to decrease until no wave V is seen
- Once you think you have threshold, **MUST REPEAT AT THIS INTENSITY**
- Can be then plotted onto a graph

Interpretation: Threshold ABR

- Clicks usually used, but be careful as there is no longer agreement that this is representative of 2-4KHz only.
- In Normalsand CHL, click threshold is usually 10 to 20 dB higher than the best HF audio threshold
- For Cochlear losses, this figure is reduced to about 5-10dB.
- Have a standard for your clinic and stick to it (10?)
- Maximum output for clicks is between 90-100dB so it will be difficult to differentiate between severe and profound losses.
- No wave V at max outputs does not mean NO HEARING!!

Tone Burst ABR

- Currently being used for NHSP rather than clicks in many centres
- Allows for some “frequency specificity” in ABR testing
- Usually testing 1 KHz and 4KHz
- Latency differences with different frequency stimuli
- Particularly low frequency burst like 500Hz requires different settings (filter)- has a broadened response/waveform. Filter needs to account for this.

Tone Burst ABR

- Wave V may not be a valid indicator of peripheral hearing sensitivity in these cases.
- **ABR is generated sub-cortically, does not truly measure “hearing”**
- **It is assessing the integrity of the peripheral auditory system and brainstem pathways BEFORE it reaches the cortex**
- Cortically deaf patients will have normal ABRs.

Tone Burst ABR

- ABR may overestimate the degree of HL.
- Patients with no ABR at maximum output levels have normal hearing on behavioural tests
- In these instances, very important to do OAEs, as patients with Auditory Neuropathy, classically will exhibit this pattern (Berlin, 1998, 2008)
- While this is considered to be the Gold standard in Audiology testing, it must form part of a battery and should not be relied upon in isolation.

Which ABR and why?

THRESHOLD

- Hearing testing in DTT population
- Wave V
- Latency and amplitude
- Test protocol
- Time to test
- Medico-legal

NEURO-OTO

- Diagnostic
- Adult vs. paed
- Wave I to V
- Latencies
- IPL
- IAVD
- Test Protocol
- Generator sites

References

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- Chapter 19 **The Auditory Brainstem Response** by Arnold in “Audiology Diagnosis” edsRoeser, Valente and Hosford-Dunn published by Thieme.
- http://hearing.screening.nhs.uk/audiologyprotocols
- **Katz Chapters 13 and 14** (6th edition) Handbook of Clinical Audiology.