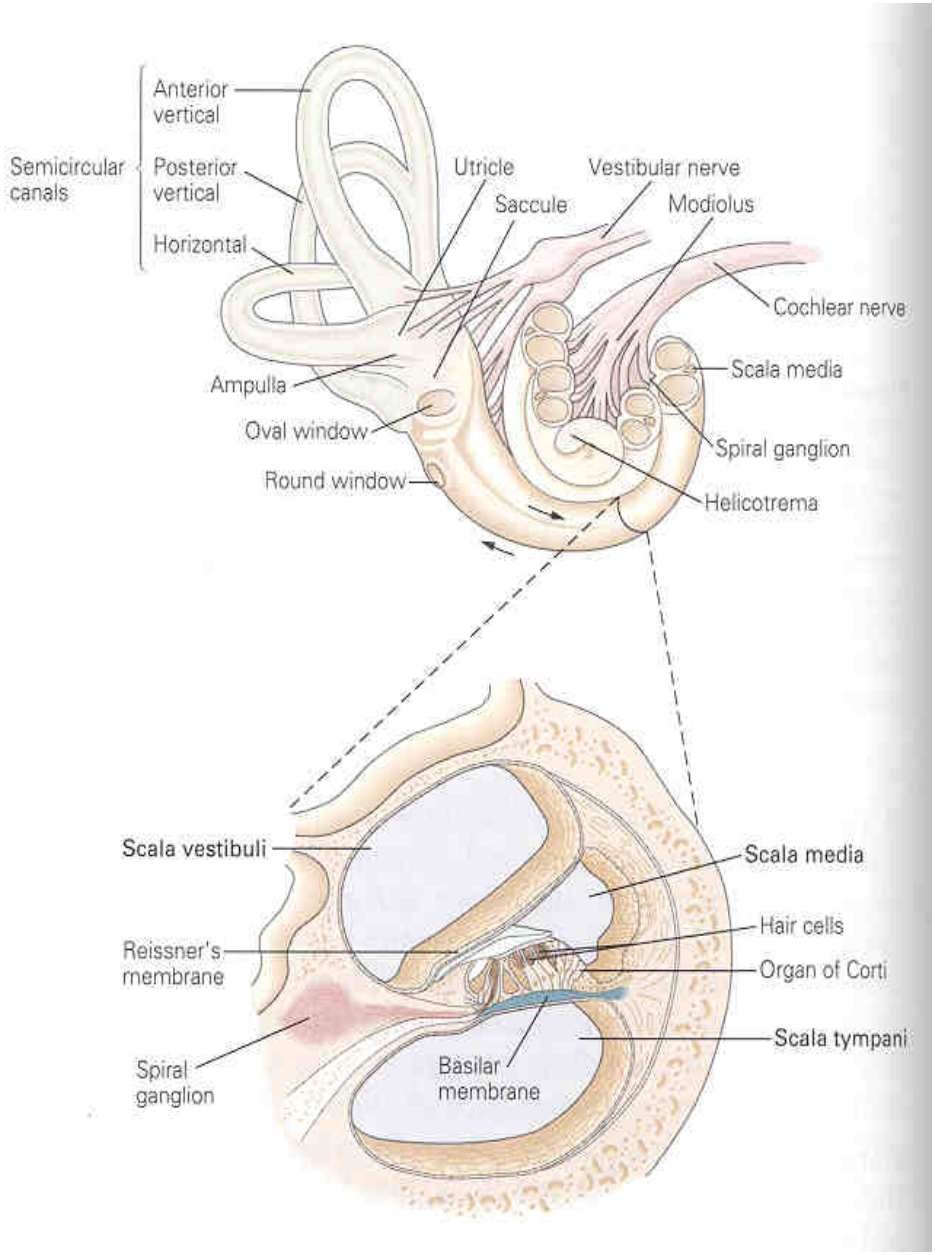
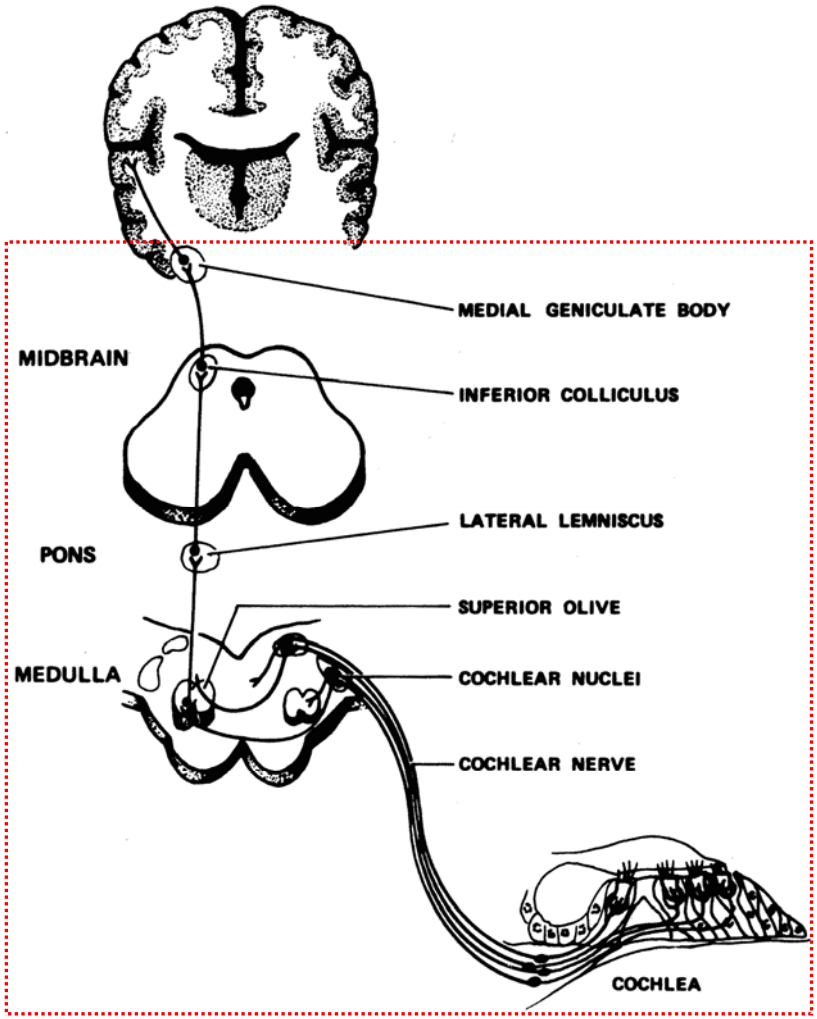
Biopotentials related with Hearing

Auditory Pathway





Sources of ABR
(lower part of auditory system)

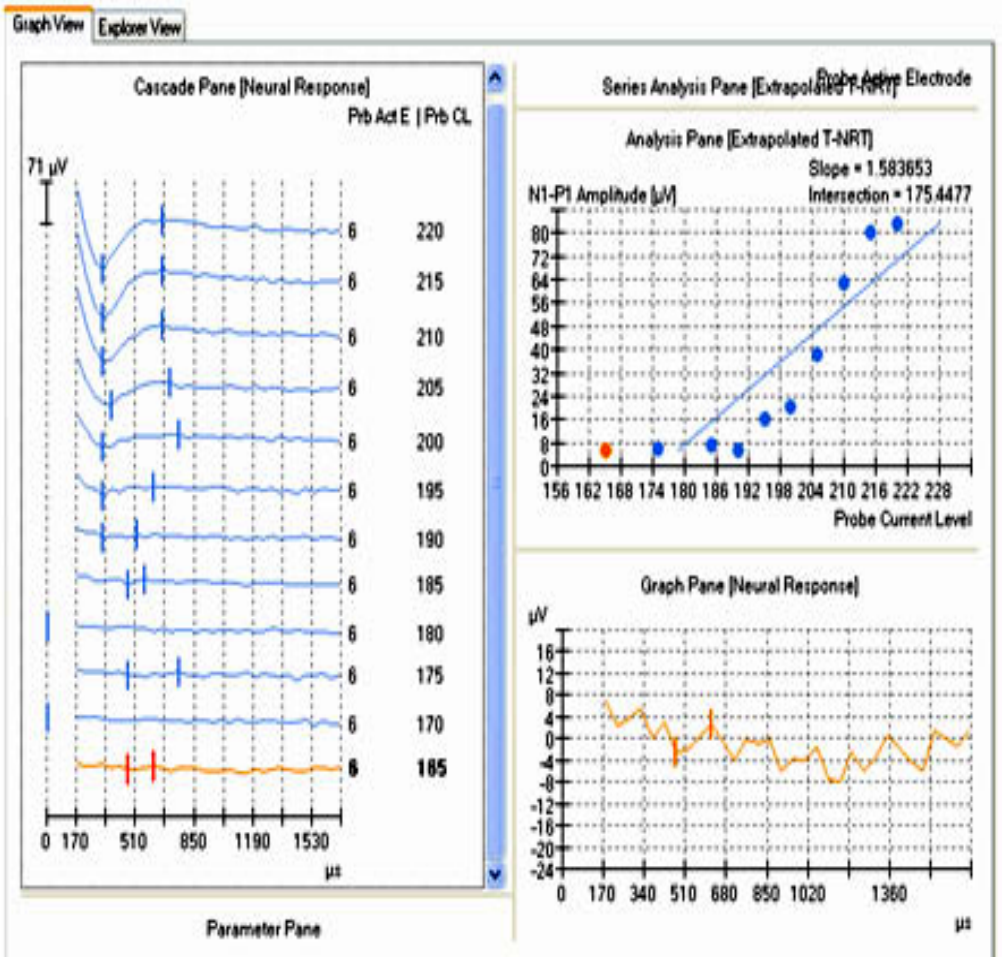
Comopound Action Potential (ECAP)

- **Electrically evoked potentials of auditory neurons.**
  - Very short latency (0.2 to 0.5msec)
  - Artifact removal is the most important techniques for successful ECAP measure

- **Cochlear stimulating electrodes are used as recording electrodes**

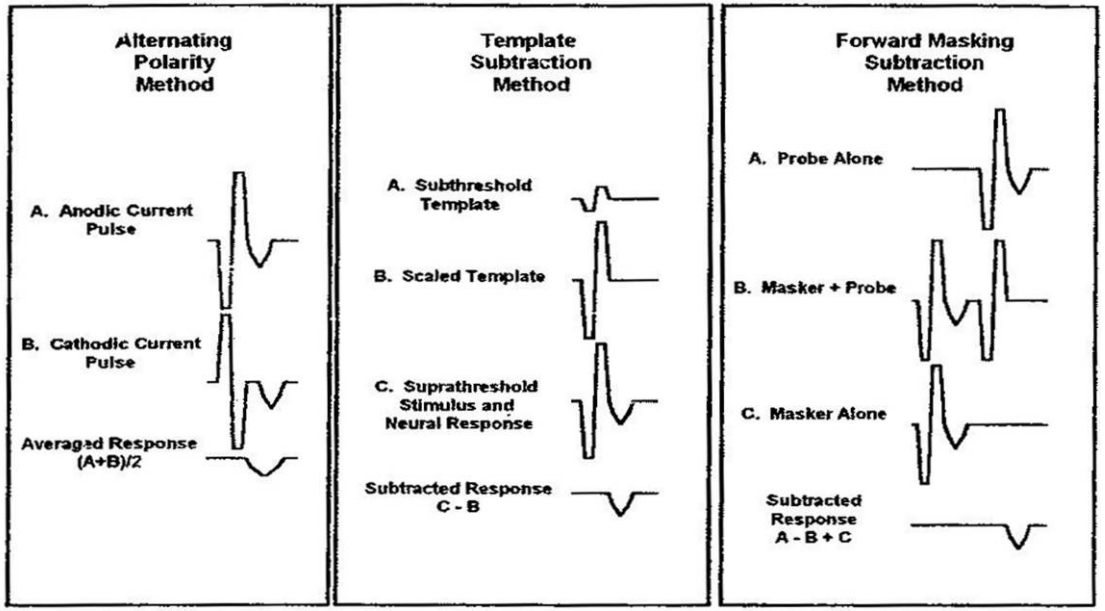
- **Every Cochlear Implant Manufacturers offer functions for ECAP masure/analysis**

(1) Cochlear Corp.
  – "NRT(Neural Response Telemetry)"
(2) Advanced Bionics
  - "NRI (Neural Response Imaging)"
(3) Med-El
  - "ART(Auditory nerve Response Telemetry)"



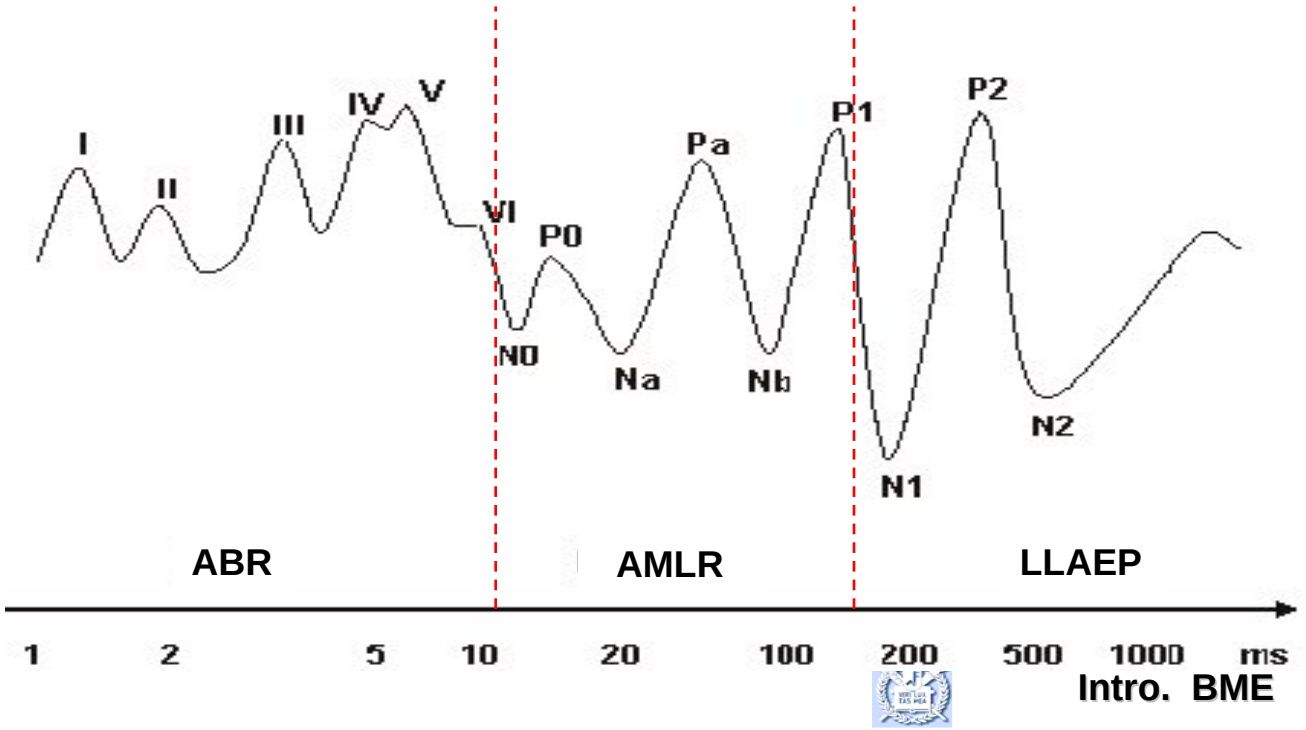
Artifact Removal in ECAP measure

- **Alterating stimulus polarity (Brown *et al*.,1990)**
  - relatively simple approach (used by Advanced Bionics Corp.)
  - underlying assumption : “the neural response is identical either anodic or cathodic leading pulses.” (but not always true (Van den Honert and Stypulkowski, 1987, Miller et al., 1998)
- **Template subtraction (Miller *et al*., 1998)**
  - use subthreshold response as a template (very linear and acurate amplifier is needed)
  - can be used with wide range of stimulus duration.
- **Two-pulse subtraction (Brown *et al*., 1990, Abbas *et al*., 1999)**
  - the most commonly used (Ineraid → Cochlear Corp., → Advanced bionics)
  - uses forward masking paragigm (refractory characteristic of neurons)
  - need careful optimization of amplifier gain and another parameters



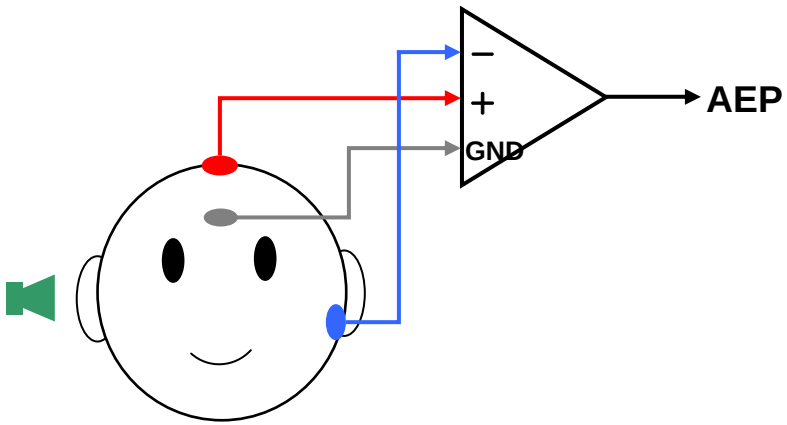
Auditory Evoked Potential (AEP)

- ABR, AMLR, LLAEP, etc.
- Tests are far field recordings of neurophysiological responses to auditory stimulation…in a bioelectric background!
- Can be measured using acoustic sound or electrical stimulation (C.I.)
- Used to identify auditory dys-synchrony (auditory neuropathy), a dysfunction of neural pathways



AEP Measure

- **AEP can be measured non-invasively**
  - scalp electrode is used.
- **Setup for AEP measure**
  (1) Recording electrode – scalp electrode
  (2) Stimulator
  - for acoustic stimulation : speaker
    (click or tone-burst sound)
  - for electrical stimulation : C.I. or other stimulator
  (3) Acquisition hardware
  - Amplification, filtering
  - data recording/analysis



Typical electrode montage for AEP measure
Vertex : non-inverting input
Forehead : groung
Contralateral earlobe : inverting input

Auditory Brainstem Response (ABR)

Most well known AEP

- Primarily used to evaluate neurological disorders at level of auditory nerve and brainstem

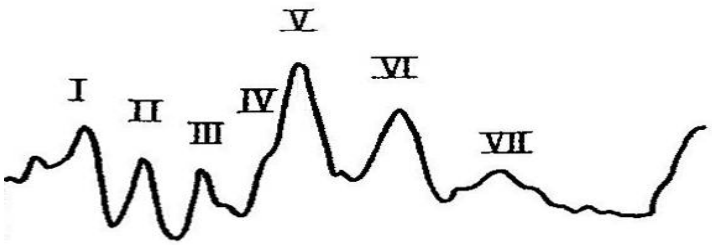
ABR (first described by Jewett and Williston, 1971)

- Short latency (~10msec) evoked potential
- ABR measure can access lower part of the auditory system
- Amplitude ranges a few uV

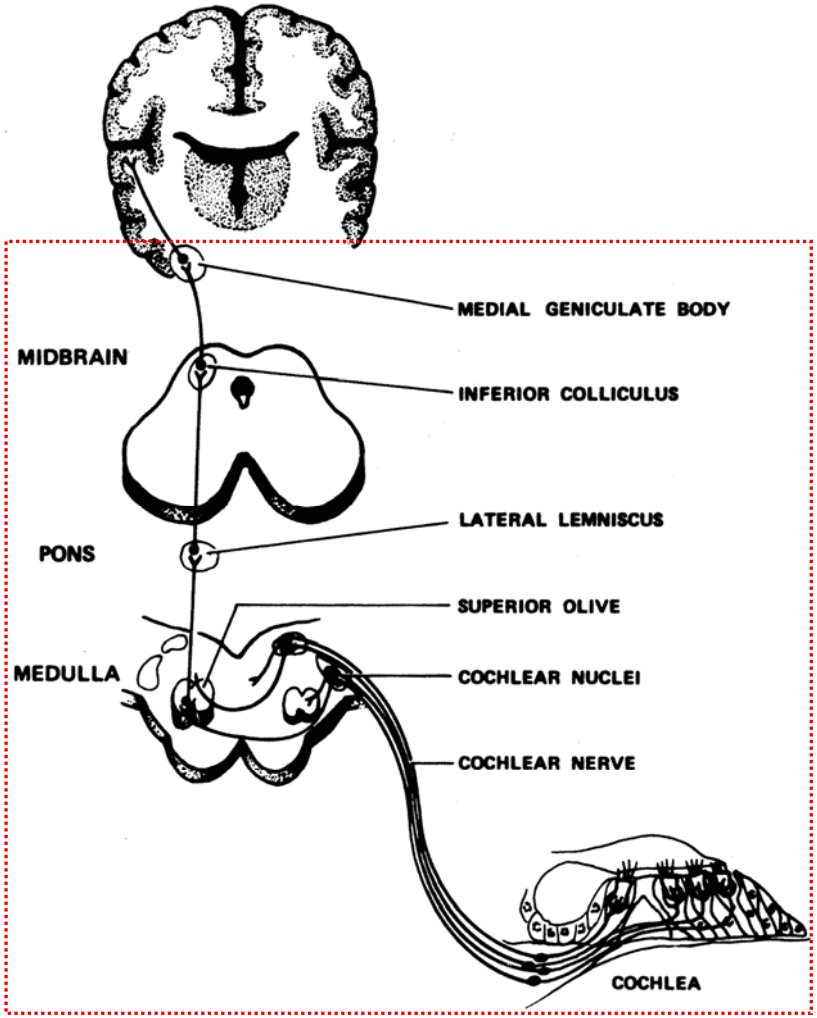
ABR consists of 7 peaks

Wave I - compound action potential of cochlear nerve
Wave II – proximal region of cochlear nerve
Wave III – cochlear nucleus
Wave IV – superior olivery complex
Wave V – lateral lemniscus
Wave VI and VII – inferior colliculus

(Presence of Wave V found to be reliable estimate of hearing ability in 2K-4K Hz range)



Typical ABR waveform



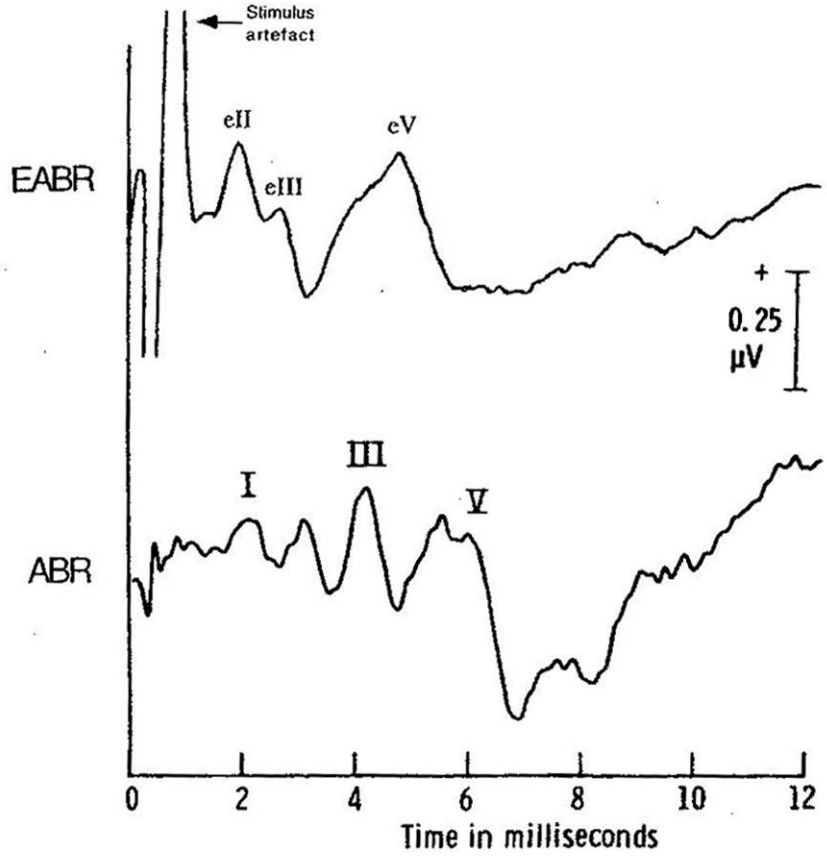
Sources of ABR
(lower part of auditory system)

ABR vs. EABR

- **EABR (Electrically evoked ABR)**
  : ABR evoked by electrical stimulation (such as C.I.)

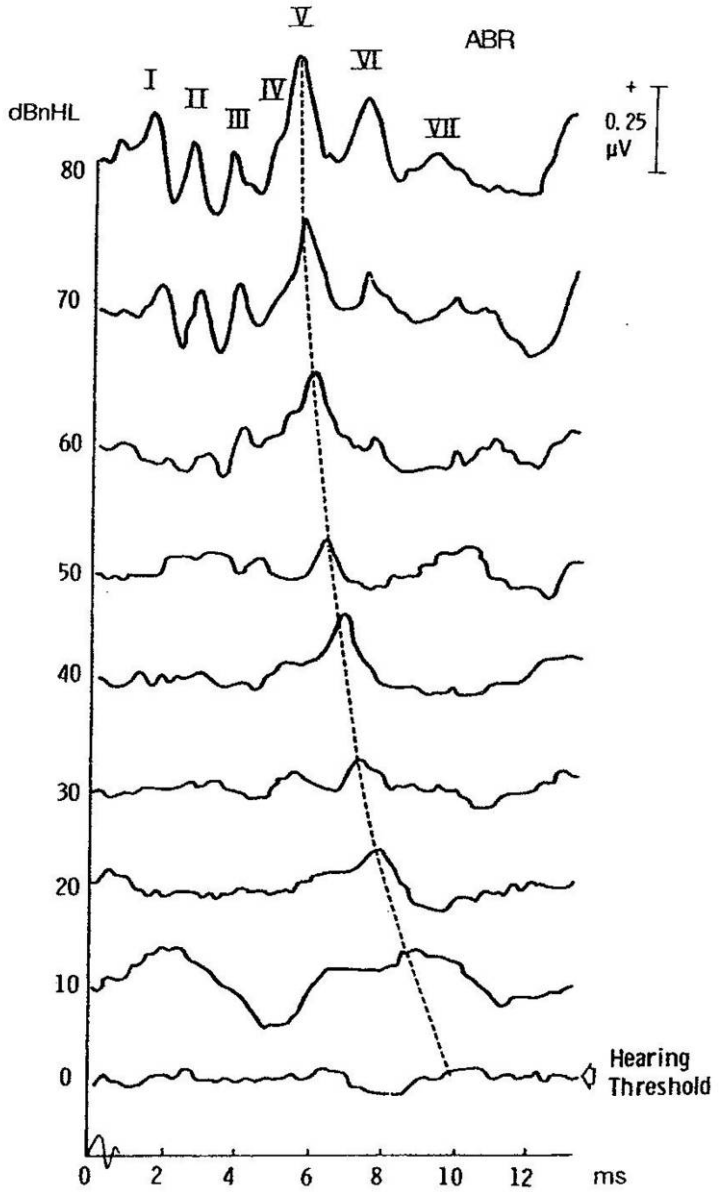
- **EABR has similar characteristic to ABR**
  - same auditory processes are used.

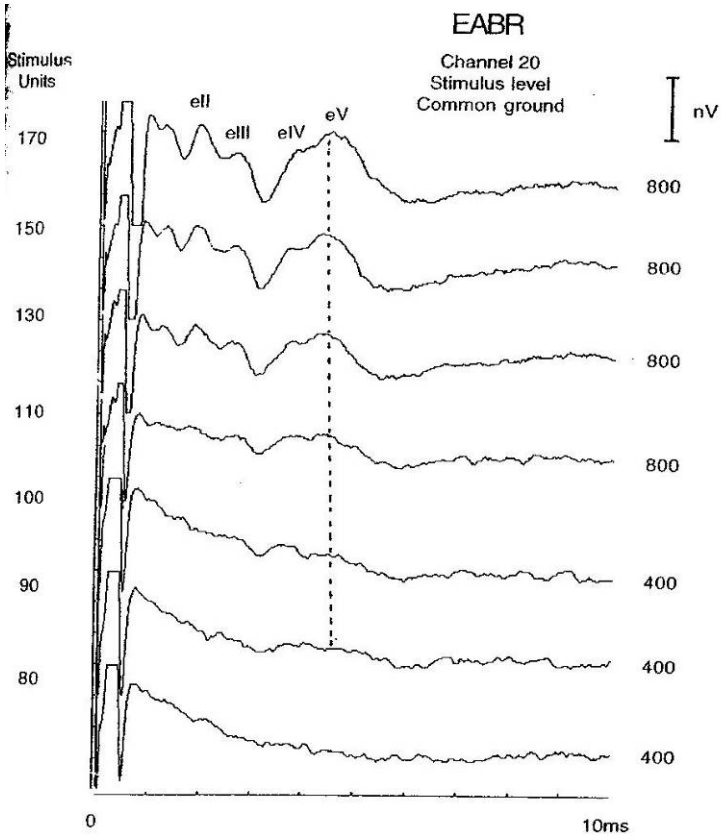
- **Some importane differences**
  (1) Wave eI is usually obscured.
  - due to stimulation artifact
  (2) Shorter latency
  - EABR arise 1.0~1.5msec earlier than ABR
  - Electrical stimulus bypasses the transmission process of sound.



Typical response wave forms for the ABR and the EABR

Intensity series of ABR and EABR





Other AEPs – AMLR, LLAEP, etc.

- AMLR Auditory Middle Latency Response

- LLAEP Long-Latency Auditory Evoked Potential
  - P300 Event Related Response

- On-going studies regarding clinical utility of these tests continue…

- Most recorded since 1960s
  : Not in widespread use outside of research sites

Auditory Middle Latency Response (AMLR)

AMLR

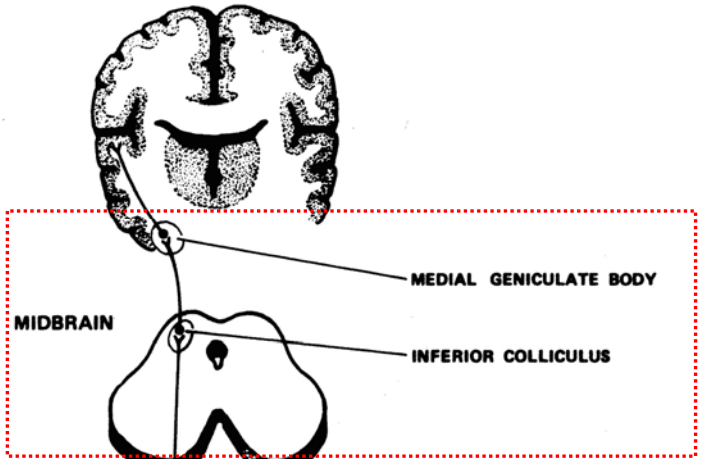
- AEP that occurs after the ABR
- Typical latency : 10msec ~ 100msec

AMLR contains larger and broader peaks than those of ABR

- Na,Pa, Nb, Pb(o P1) peaks
(This form of representation is introduced by Goldstein and Rodman, 1967)
- Pa is mostly used for checking auditory function (often compared to wave V of ABR)
- Pb is highly variable and may not appear in normal subjects

AMLR measure is helpful in studying central auditory function in patient with language, speech and learning

- Neural generator of AMLR
(1) subcortical portion of the auditory pathway that develops early
(2) cortical portion that developes later



Sources of AMLR

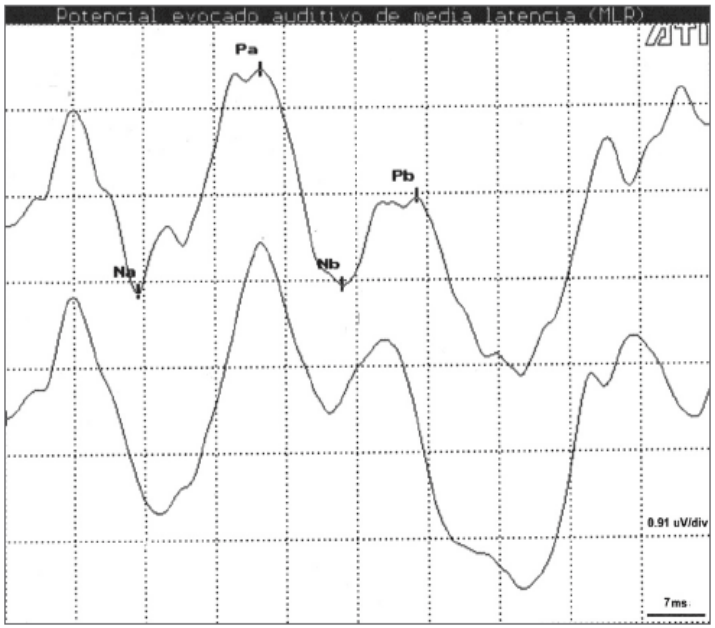


Figure 1. AMLR recording at 70 dBNA with replication.
Key: mV= microvolts; ms = milliseconds.

Long Latency Auditory Evoked Potential (LLAEP)

LLAEP is results of cognitive processing

- related with cognitive function of brain rather
  (than with physical sensory input)
- P300 event related potential is mostly invested by researchers

P300 event-related potential (Sutton et al, 1965)

- Positive peak with latency around 300msec after stimulation
- late cognitive component

Clinical use of P300

- diagnosis of
  (1) epilepsy, (2) Alzheimer disease,
  (3) obsessive-compulsive disorder, etc.