Review Article

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Auditory Brainstem Response (ABR) Audiometry and its Role in Clinical Practice

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Abstract

Auditory Brain stem Response (ABR audiometry), also known as Brainstem Evoked Response Audiometry (BERA), BAER (Brainstem Auditory Evoked Response audiometry), BAEP (Brain Auditory Evoked Potential) was first described by Jewett and Williston in 1971. It is a neuro- physiological test of auditory brainstem function and is an objective way of eliciting brain stem potentials in response to audiological click stimuli. ABR typically uses a click stimulus that generates a response from the hair cells of the cochlea, the signal travels along the auditory pathway from the cochlear nuclear complex to the inferior colliculus in mid brain and generates wave I to wave V. These waves are recorded by electrodes placed over the scalp. Even though ABR provides information regarding auditory function and sensitivity, it is not a substitute for other methods of audiological evaluation. It should be always viewed in conjunction with other audiological investigations.

Keywords: Auditory, Brain stem, Audiometry, Evoked.

Introduction

Auditory brainstem response (ABR) audiometry is a neurologic test of auditory brainstem function and is an objective way of eliciting brain stem potentials in response to audiological click stimuli. These waves are recorded by electrodes placed over the scalp. ABR audiometry is the most common application of auditory evoked responses. Test administration and interpretation is typically performed by an audiologist.

Auditory Brain stem Response (ABR audiometry), is also known as Brainstem Evoked Response Audiometry (BERA), BAER (Brainstem Auditory Evoked Response audiometry), BAEP (Brain Auditory Evoked Potential). This investigation was first described by Jewett and Williston in 1971. It was in 1967 Sohmer and Feinmesser who published the first recording of cochlear potentials using surface electrodes in humans. They erroneously attributed all the waves generated to the potentials arising from cochlea. The fact that these potentials can be recorded in an non -invasive manner excited one and all. In 1975 it was Starr and Achorwhoreported the effects of ABR (auditory brain stem response) in patients with pathology in the brain stem. In 1977 Selters and Brackman described the importance of prolonged interpeak latencies in patients with acoustic tumors. They also postulated that this time delay was directly proportional to the size of the tumor.

Even though ABR provides information regarding auditory function and sensitivity, it is not a substitute for other methods of audiological evaluation. It should be always viewed in conjunction with other audiological investigations.

Principle of ABR

ABR typically uses a click stimulus that generates a response from the hair cells of the cochlea, the signal travels along the auditory pathway from the cochlear nuclear complex to the inferior colliculus

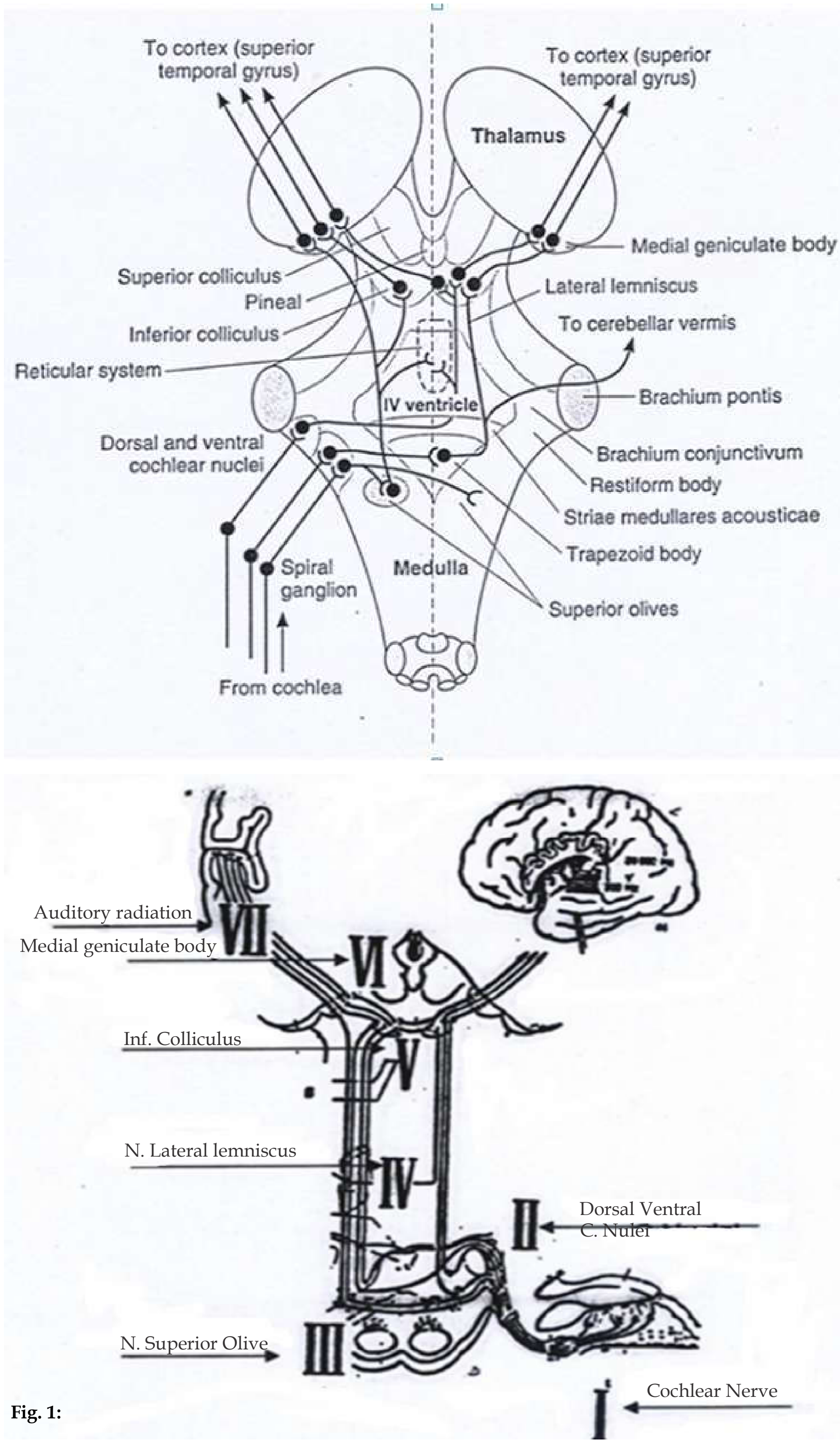

Fig. 1:

in mid brain and generates wave I to wave V.

Method of recording ABR

The stimulus either in the form of click or tone pip is transmitted to the ear via a transducer placed in the inserted ear phone or head phone. The wave forms of impulses generated at the level of brain stem are recorded by the placement of electrodes over the scalp.

Electrode placement

Since the electrodes should be placed over the head, the hair must be oil free. The patient should be instructed to have shampoo bath before coming for investigation. The standard electrode configuration for ABR involves placing a non inverting electrode over the vertex of the head, and inverting electrodes placed over the ear lobe or mastoid prominence. One more earthing electrode is placed over the forehead. This earthing electrode is important for proper functioning of preamplifier.

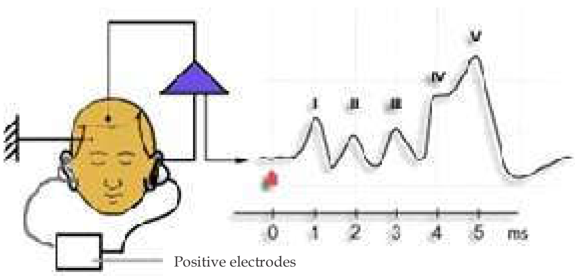

Fig. 2: showing placement of BERA electrodes

Since the potentials recorded are in far field, well displaced from the site of impulse generation, the wave forms recorded are very weak and they need to be amplified. This amplification is achieved by improving the signal : noise ratio.

Three parallel approaches are designed to improve signal to noise ratio.

- Filtering: This is employed to reduce the recording bandwidth so that only the important components of the signal generated are recorded.
- Repeated stimulation: This is done with synchronous time domain averaging to increase the amplitude of the components of the signal. In real time situations these two can be achieved by connecting the recording electrodes to a preamplifier, with appropriate filter settings.
- Polarity alteration: By altering the polarity of impulses recorded, the artefacts are cancelled making the brain stem waves stand out.

The amplitude (microvoltage) of the signal is averaged and charted against the time (millisecond), much like an EEG. The waveform peaks are labelled I- VII. These waveforms normally occur within a 10 millisecond time period after a click stimulus presented at high intensities (70 - 90 dB normal hearing level [nHL]).

In ABR, the impulses are generated by the brain stem. These impulses when recorded contain a series of peaks and troughs. The positive peaks (vortex positive) are referred by the Roman numerals I – VII, of which waves I, III and V are the most visible and of more significant clinical value.

These peaks are considered to originate from the following anatomical sites:

Table 1:

Wave	Site
I	Cochlear nerves
II	
III	Cochlear nucleus
IV	Superior olivary complex
V	Nulclei of lateral lemniscus
VI	Inferior colliculus
VII	

These peaks occur in most readable form in response to click stimuli over a period of 1 - 10 milliseconds after the stimulus in normal hearing adults.

ABR is resistant to the effects of sleep, sedation, sleep and anesthesia. Its threshold has been found to be within 10 dB as elicited by conventional audiometry.

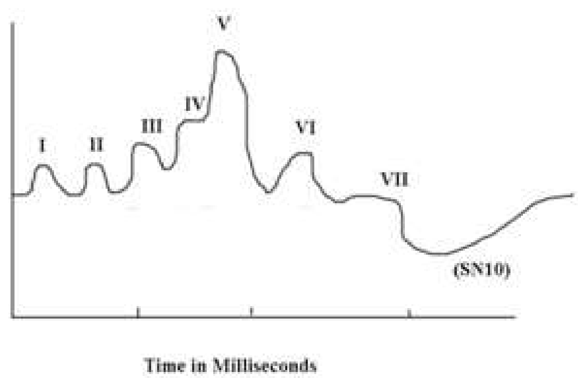

Fig. 3:

Interpretation:

Recordings of this potential may be clinically analyzed according to a number of parameters: morphology; absolute latency and wave I, III and V amplitude; I-III, I-V and III-V interpeak interval latencies; I-V latency andamplitude relation; and I-V interval interaural differenceor wave V absolute latency difference. Absolute latencyand interpeak interval measurements are those most widely used clinically.

Table 2:

Wave	Observation	Indicates
I	small amplitude, delayed or absent	cochlear lesion
V	small amplitude, delayed or absent	upper brainstem lesion
I – III	inter-peak latency: prolongation	lower brainstem lesion.
III – V	inter-peak latency: prolongation	upper brainstem lesion
I – V	inter-peak latency: prolongation	whole brainstem lesion

Shortening of wave, the interval with normal latency of wave V indicate cochlear involvement.

Factors affecting ABR

1. Stimulus rate
2. Stimulus phase or polarity
3. Intensity of sound stimulus
4. Binaural/monaural stimulation
5. Filter characteristics of ABR machine
6. Nature of sound
7. Age and sex of patient

Usefulness of ABR

- ✓ Detection and quantification of deafness in infants, mentally retarded, malingering or deeply sedated subjects
- ✓ Objective determination of nature of deafness in difficult to test patients
- ✓ Identification of the site of lesion in retro-cochlear pathologies
- ✓ Study of central auditory disorders
- ✓ Study of maturity of CNS in newborns

- ABR is a valuable objective measure of hearing. With decreasing stimulus intensity, wave latencies increase systematically until the hearing threshold is reached. Below this hearing threshold the response is absent. Thus it is possible to estimate hearing threshold even in individuals who cannot be tested by behavioural methods. It should be borne in mind that adult like ABRresponses are acquired only after the age of 2.
- It is possible to test new-born's hearing using ABR, using age appropriate norms.
- ABR is unaffected by sleep or sedation hence infants can be sedated before performing this test.
- Can be used to detect demyelinating lesions involving auditory pathways.
- Can be used to detect lesions and tumours involving auditory pathway.
- Italsohelpstheneurosurgeoninintraoperative monitoring of the audio vestibular system during extensive neurosurgical procedures involving this area.
- ABR is very useful in identification of retrocochlear pathologies causing hearing loss. ABR findings that indicate retrocochlear pathology includes:
  - ➢ Latency differences between inter-aural wave V (prolonged in cases of retrocochlear pathology)
  - ➢ Waves I - V inter-aural latency differences - prolonged
  - ➢ Absolute latency of wave V - prolonged
  - ➢ Absence of brain stem response in the affected ear
- ABR has 90% sensitivity and 80% specificity in identifying cases of acoustic schwannoma. The sensitivity increases in proportion to the size of the tumor.
- Currently ABR is extensively being used in screening neonates for deafness. Since this is a complicated investigation only "high risk infants" are screened at present. Indications for screening ABR in an infant are:
  - ➢ Parental concern about hearing levels in their child
  - ➢ Family history of hearing loss
  - ➢ Pre and post natal infections
  - ➢ Low birth weight babies
  - ➢ Hyperbilirubinemia
  - ➢ Craniofacial deformities
  - ➢ Head injury
  - ➢ Persistent otitis media
  - ➢ Exposure to ototoxic drugs
- Even though typical ABR recordings are performed using short duration simple stimuli like clicks, complex sounds like human voice with long duration can also be used in ABR. ABR responses to speech sounds can be used as a marker to identify complex

disorders involving auditory processing.

Fallacies of ABR

- A high frequency purely cochlear deafness may present BERA features that mimic a neural lesion. To study BERA for site of lesion studies, the nature of deafness in audiogram needs to be taken into account.
- Although the ABR provides information regarding auditory function and hearing sensitivity, it is not asubstitute for a formal hearingevaluation,andresultsshouldbeused in conjunction with behavioralaudiometry whenever possible.
- For an acoustic neuroma to cause abnormalities in the BERA, the tumour mass should exert sufficient pressure on a sufficient number of high frequency fibres to sufficiently block or desynchronize those nerve fibres. If this is not attained, then BERA findings will be normal in spite of a tumour.

Auditory Steady-State response (ASSR)

ASSR is an auditory evoked potential, elicited with modulated tones that can be used to predict hearing sensitivity in patients of all ages. It is an electrophysiological response to rapid auditory stimuli and creates a statistically valid estimated audiogram (evoked potential used to predict hearing thresholds for normal hearing individuals and those with hearing loss). The ASSR uses statistical measures to determine if and when a threshold is present and is a “cross-check” for verification purposes prior to arriving at a differential diagnosis.

ABR vs ASSR

Similarities

- Both record bioelectric activity from electrodes arranged in similar recording arrays.
- Both are auditory evoked potentials.
- Both use acoustic stimuli delivered through inserts (preferably).
- Both can be used to estimate threshold for patients who cannot or will not participate in traditional behavioural measures.

Differences

- ASSR looks at amplitude and phases in the spectral (frequency) domain rather than at amplitude and latency.
- ASSR depends on peak detection across a spectrum rather than across a time vs. amplitude waveform.
- ASSR is evoked using repeated sound stimuli presented at a high rep rate rather than an abrupt sound at a relatively low rep rate.
- ABR typically uses click or tone-burst stimuli in one ear at a time, but ASSR can be used binaurally while evaluating broad bands or four frequencies (500, 1k, 2k, & 4k) simultaneously.
- ABR estimates thresholds basically from 1-4k in typical mild-moderate-severe hearing losses. ASSR can also estimate thresholds in the same range, but offers more frequency specific info more quickly and can estimate hearing in the severe-to-profound hearing loss ranges.
- ABR depends highly upon a subjective analysis of the amplitude/latency function. The ASSR uses a statistical analysis of the probability of a response (usually at a 95% confidence interval).
- ABR is measured in microvolts (millionths of a volt) and the ASSR is measured in nanovolts (billionths of a volt).

Conclusion

Auditory brainstem response (ABR) audiometry has a wide range of clinical applications, including screening for retrocochlear pathology, universal newborn hearing screening, and intraoperative monitoring. Additional applications include ICU monitoring, frequency specific estimation of auditory sensitivity, and diagnostic information regarding suspected demyelinating disorders (eg, multiple sclerosis). As technology continues to evolve, ABR will likely provide more qualitative and quantitative information regarding the function of the auditory nerve and brainstem pathways involved in hearing.

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