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Annotations

Auditory brainstem response in paediatric audiology

The functioning of the auditory system has been extensively investigated in both man and animals using recordings of electrical activity evoked by sounds. Early investigators encountered the problem of detecting the response to a sound stimulus when the background electrical noise was high. The introduction of signal averaging and the subsequent development of the digital averaging computer, however, completely revolutionised the field of electric response audiometry and it is now possible to measure electrical responses to sound from the entire length of the auditory pathway.[1]

Auditory evoked potentials are often described as early, middle, or late latency responses according to the time at which the response occurs after the auditory stimulus. Each class represents electrical activity from a progressively higher level of the auditory pathway. The electrical activity originating in the auditory nerve and brainstem pathways is known collectively as the auditory brainstem response. They form part of the early latency responses and arise in the first 10 milliseconds after an auditory stimulus. The first definitive description of the auditory brainstem response in humans was given by Jewett and Williston in 1971,[2] although Sohmer and Feinmesser first recorded these neurogenic responses in 1967.[3] Jewett showed that the response evoked by a high intensity click stimulus, and recorded from a vertex and ipsilateral mastoid electrode configuration, consists of a series of up to seven waves (designated I to VII in the Jewett classification as shown in fig 1). These waves are a far field recording of the electrical activity from sequentially activated neurones of the ascending auditory nerve and brainstem pathways.

The precise origins of these waves are not well understood and are complicated by the interaction between the possible generator sites. The proposed origins are based largely on either studies in animals,[4] patients with brainstem disorders,[5] or more recent comparative studies of surface and depth recorded auditory brainstem responses in patients undergoing surgery.[6 7] Wave I is known to be the compound auditory nerve action potential and is similar to the action potential recorded in electrocochleography.[8] Wave II is now thought to arise predominantly from proximal regions of the auditory nerve and wave III from the cochlear nucleus. The superior olivary complex is considered to be the main source of wave IV and the lateral lemniscus wave V. Waves VI and VII are thought to arise mainly from the inferior colliculus.

As well as these fast individual waves of the auditory brainstem response, as described by Jewett and Williston, there are also slow waves associated with the response which consist of a peak at roughly the same latency as wave V and a trough at a latency of about 10 milliseconds as shown in fig 1. This trough is termed a slow negative component at 10 milliseconds (SN10) by Davis and Hirsh[9] and is thought to originate in the midbrain probably representing postsynaptic activity within the inferior colliculus.[6]

The auditory brainstem response is considered by most workers to be the best choice of all the auditory evoked potentials for objective assessment of hearing acuity in young patients.[10–12] Although the audiological information provided by the auditory brainstem response is limited in some situations, the slow wave V and SN10 components can be recorded reliably with stimulus intensities close to the threshold of hearing, as shown in fig 2, and these components are resilient to the effects of habituation and sleep.

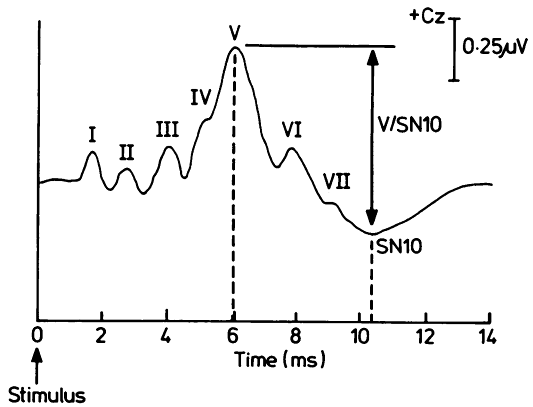

Fig 1 *The typical configuration of the auditory brainstem response.*

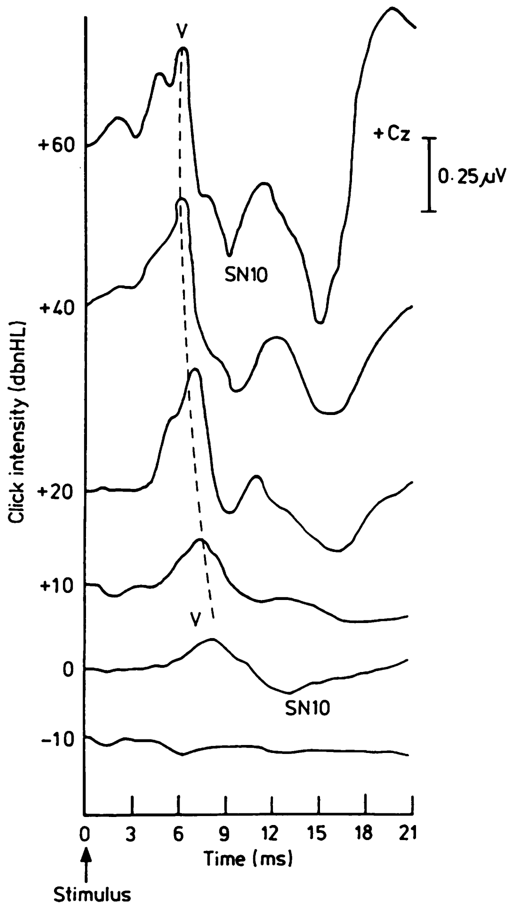

Fig 2 *Auditory brainstem responses recorded in a normally hearing subject.*

Recording the auditory brainstem response

The auditory brainstem response is measured from the differential signal across a pair of surface recording electroencephalography electrodes. One electrode is positioned over an area of high response activity (active) and a second electrode over an area of low response activity (reference). The optimum stimulus to evoke the response must be fairly abrupt so as to produce a good degree of synchrony of firing of the nerve fibres, and for this reason a click is widely used. This is generated by passing a 100 microsecond electrical pulse through a headphone and is usually calibrated in decibels above the hearing threshold of normally hearing subjects (dbnHL). The resultant acoustic stimulus has energy over a wide range of frequencies, and this results in an auditory brainstem response which is generated mainly by the basal (high frequency) turn of the cochlea. The click auditory brainstem response threshold corresponds reasonably well with the average subjective hearing thresholds across the frequency range from 2 kHz up to 4 kHz.[13]

The auditory brainstem response is very small compared with the background electrical noise and a repetitive stimulus is required so that the response-to-noise amplitude ratio can be improved using signal averaging. It is usually necessary to average about 2000 or 4000 individual sweeps in order to achieve reliable identification of the response waveform, the precise number being dependent on the recording conditions. The wave V and SN10 components are fairly resilient to fast rates of stimulation and a stimulus rate of 20 to 30 Hz can be employed without risk of adapting the response. In audiological investigations, recordings are made at different levels of stimulus intensity until a response is no longer observed and this is taken as an estimation of the hearing threshold. The stimulus intensity is usually changed in steps of 10 db close-to-threshold rather than 5 db (because of time constraints) and the threshold is estimated to the nearest 5 db using interpolation. Usually, in routine investigations, the test does not continue below a stimulus level of 20 db above the threshold of normal hearing.

The merits and limitations of tests for auditory brainstem response

The auditory brainstem response is a valuable audiological test for the very young or the otherwise difficult to test child. It does not, however, offer a panacea to replace conventional testing and children should only be referred for electric response audiometry when conventional tests have failed to provide reliable or adequate results. From a well documented paediatric audiology service with an open access referral system it has been found that electric response audiometry support is needed only in approximately 3% of the total caseload.[14] The auditory brainstem response is particularly valuable in the important first few weeks of life when behavioural observation testing can be difficult to carry out.

In recent years equipment costs and the ease and convenience of equipment use have made the auditory brainstem response technique more accessible to inexperienced or non-scientific personnel, and it is therefore very important to consider the following factors before applying the technique in a routine audiological service.

(1) The procedure can be time consuming.

(2) The environment in which the test is

performed must be free from high levels of acoustic and electrical interference.

(3) Sedation or anaesthesia may be needed for young children in order to achieve satisfactory recording conditions.

(4) Skill in interpretation of the auditory brainstem response waveforms is required.

The auditory brainstem response can be a time consuming procedure particularly when recording conditions are not ideal. Most young babies (below 6 months) will settle and sleep sufficiently to allow the test to be carried out satisfactorily without any sedation. The difficult age group is between one to three years and some of these children will need sedating. Only in exceptional circumstances should it be necessary to resort to the use of anaesthetics.

Interpretation of the auditory brainstem response waveforms requires a high level of expertise and experience and it may be quite difficult to recognise a genuine response among the background noise, particularly when the recording conditions are not ideal. This situation can easily lead to a misinterpretation of the hearing threshold. The click evoked response also provides limited audiological information compared with conventional tests because although clicks give a reasonable measure of high frequency response they do not provide information about the hearing at low frequencies. A low frequency conductive hearing loss would not be identified with click stimuli and, conversely, results from a patient with a steeply sloping high frequency loss could be misinterpreted to show a much more severe hearing impairment than in fact exists. The use of tone pips at lower frequencies than the click, down to about 1 kHz, can provide some indication of hearing thresholds in the mid to low speech frequency region and will help to differentiate between these cases of low and high frequency hearing impairment.[15 16] Good recording conditions are required for reliable identification of the tone pip auditory brainstem response as the response waveform is not as clearly defined as for the click response.

Another limitation of the test for auditory brainstem response is that unlike subjective audiometry, including speech tests of hearing, it does not sample the entire auditory pathway and hearing disorders of central origin cannot be investigated.

If hearing aids are recommended, initially on the basis of electric response audiometry measurements, follow up testing by conventional means should always be carried out wherever possible both before and after the provision of hearing aids. The conventional tests are needed to provide a more comprehensive audiological picture including measures of sound tolerance, aided and unaided threshold comparisons, acoustic dynamic range, and, where possible, speech audiometry.

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S Mason
Queens Medical Centre, Nottingham
B McCormick *and* S Wood
General Hospital, Nottingham