

## Guideline 11 C: RECOMMENDED STANDARDS FOR INTRAOPERATIVE MONITORING OF AUDITORY EVOKED POTENTIALS

Surgical procedures within the posterior and middle cranial fossa may be complicated by postoperative deficits caused by damage of the auditory nerve or brainstem. Some of these deficits may be secondary to vascular manipulation or mechanical traction of neuronal structures. Neurophysiologic intraoperative monitoring (NIOM) with auditory evoked potentials represents an objective method of monitoring auditory nerve and brainstem functions during these surgical procedures. Although auditory nerve action potentials have been recorded directly from the exposed nerve, most of the clinically useful intraoperative experience has been obtained with brainstem auditory evoked potentials (BAEPs). {Harper, 1998 #43; Legatt, 2002 #40} Most of the following discussion will be about the intraoperative use of BAEPs.

### A. Terminology

The "vertex-positive" components of BAEPs are designated by the roman numerals I through V. This nomenclature and the methodology used to identify the waveforms is discussed in Guideline 9C. {ACNS, 2006 #18}

### B. Stimulation

#### 1. Stimulus Delivery

In the operating room, auditory stimulation with broad-band clicks is preferred. Each clicks should be generated by a single 100- $\mu$ s monophasic square wave pulse. Comfortable earplugs connected to a transducer are generally used for stimulation. If compressible tubing is used to connect the earplugs to the transducer, care should be taken to avoid obstruction of the tubing system that would lead to failure of sound transmission. In-ear speakers are an acceptable alternative. Earplugs connected to a transducer or in-ear speakers should be protected from blood and fluids by waterproof adhesive tapes. Prior to placement of earplugs, otoscopic visualization of the external auditory canal is useful to confirm patency. Excessive cerumen that could interfere with the auditory stimulation should be cleared prior to the monitoring.

Clicks should be delivered monaurally, i.e., one ear at a time. Although the ear ipsilateral to the site of surgical intervention may be continuously stimulated and monitored, the contralateral ear should also be stimulated at regular intervals to check for developing asymmetry, latency, and amplitude differences. When stimulating the ears sequentially, the nonstimulated ear should be masked with a white noise at 60 dB pe SPL or 30-35 dB HL to eliminate "crossover" responses, i.e., bone-conducted responses originating in the nonstimulated ear. Modern NIOM equipment has the ability to deliver interleaved stimulation. This effectively allows simultaneous averaging of left and right ear stimulation. However, interleaved stimulation does not allow contralateral masking. This is not a significant problem intraoperatively, as lack of masking will not prevent recognition of auditory pathway compromise. {Legatt, 2008 #44}

#### 2. Stimulus Intensity

Click intensity of 100 dB pe SPL or 60-70 dB HL is commonly utilized. If pre-existing hearing loss is present, higher click intensities may be needed. During surgery, if fluid collects in the middle ear higher intensity stimulation may be needed to obtain BAEPs.

### 3. Stimulus Polarity

Alternating polarity clicks are used most often intraoperatively since they minimize stimulus artifact. This becomes particularly important when clicks of higher intensity are used.

### 4. Stimulus Rate

Stimulus rates of 5-12/s result in optimal resolution of peaks I, III, and V. Faster stimulus rates of 30/s may allow for more rapid acquisition of the most important components (usually waves I and V), however other components (usually wave III) are degraded. {Burke, 1999 #14} Stimulus rates that are multiples of the line current frequency (60 Hz in North America) should be avoided. Fine adjustments of stimulus frequency (such as a rate of 10.1/s) often help eliminate line noise artifact from recordings. Whatever stimulus rate is selected should be maintained throughout the recording. If it is changed, the baseline must be reestablished.

## C. Recording

### 1. System Bandpass

Filter settings of 100 – 150 to 2,500 – 3,000 Hz (-3dB) are typically used. If excessive high frequency artifact is present, the high frequency filter can be reduced to 1,000 Hz. Additionally, a line current frequency filter can be used without significant effect on the waveforms. However, filter settings must be kept constant throughout a particular surgical case. Changes in filter setting during a case will cause changes in the responses that can be erroneously interpreted as being due to pharmacologic or surgical factors.

### 2. Analysis Time

Analysis time should be 15 ms from stimulus onset. A short time of 10 ms is used for outpatient BAEP studies, but this may be too short for surgical monitoring. Lower temperature in the operating room, pre-existing pathology, and operative trauma can cause prolongation of the BAEP waveform beyond 10 ms.

### 3. Number of Trials to be Averaged

A sufficient number of trials must be averaged to obtain an interpretable and reproducible BAEP. Generally 500 – 1000 trials are needed; the actual number of trials depends on the amount of noise present and the amplitude of the BAEP signal itself. With small amplitude waveforms or excessive noise, more trials may be needed.

### 4. Electrode Type and Placement

Either standard disk EEG electrodes or sterile subdermal needle electrodes may be used to record BAEPs. Disk EEG electrodes should be applied to the scalp with collodion. They should be sealed with plastic tape or sheet to prevent drying and provide protection from blood or other fluids. For disk EEG electrodes, impedance should be < 5Kohms. Subdermal needle electrodes should be similarly secured. It is important that the operating room personnel be made aware of the use of and locations of the subdermal needle electrodes, so that they may observe necessary caution to avoid needle sticks.

Recording electrodes are placed at Cz and over the left and right mastoid processes (M1 and M2) or anterior to each ear, over the preauricular notch (A1 and A2).[\[add reference for 10-20 system\]](#) For patients undergoing suboccipital craniotomies, the later position may be preferable. The Cz electrode may be moved anteriorly if necessary to avoid the surgical field. The ground electrode is usually placed at Fz.

#### 5. Near-Field Recordings

Auditory nerve action potential (NAP) can be recorded directly from the nerve after exposure. An electrode is placed directly on the proximal part of the auditory nerve by the surgeon. Stimulation is provided in a manner similar to that used for recording BAEPs. Because of the large signal to noise ratio, very few trials are needed to obtain reproducible responses. Auditory NAPs are very sensitive to changes in conduction and allow quick identification of neural compromise. Such compromise is manifest by prolongation of NAP latency or reduction of amplitude. Alert parameters similar to those used for BAEPs are used for NAPs. The major disadvantage of auditory NAPs is that they can only be obtained after exposure and monitoring must be discontinued during closing. Additionally, the surgeon must place the electrode, increasing the complexity of the surgery. {Moller, 1988 #50}

#### 6. Montage

A minimum of two-channel recording is advisable. The following montage is suggested:

Channel 1: Cz-Mi

Channel 2: Cz-Mc.

In this montage 'i' and 'c' refer to the side of stimulation, ipsilateral and contralateral. Instead of Mi and Mc, Ai and Ac can also be used. If a third channel is available, Mi-Mc (or Ai-Ac) derivation can be used. This allows better identification of the wave I as this waveform has a horizontal dipole, with the negativity ipsilaterally and positivity contralaterally.

#### D. Analysis of Results and Criteria for Abnormalities

Measurements of absolute latencies and amplitudes of waves I and V and I-V interpeak latency should be made on baseline recordings. Amplitude is measured from the vertex positive peak to the aftergoing negative trough. It is essential that these baseline BAEPs be recorded using the same parameters for stimulation and recording that are to be used for intraoperative monitoring. Stacked plots of sequentially recorded BAEP averages are helpful during the course of the operation.

Complete measurements of all the various waves and their interpeak latencies is too time consuming during intraoperative monitoring. However, continuous monitoring of the absolute latency and amplitude of wave V should be carried out. Significant changes in the wave V latency should be reported to the surgeon. At times the wave V is poorly defined, and the wave IV is the dominant waveform in the wave IV-V complex. In these cases, the latency and amplitude of the wave IV should be followed closely. Evaluation of the Cz-Ac derivation may help identify the wave V as there is greater separation of waves IV and V in this derivation.

Interpretation of intraoperative BAEPs is performed by comparing each sequential average to the baseline obtained at the start of the surgery. Each patient serves as his or her control. Typical criteria of BAEP change used for alerting the surgeon is a 1 ms latency prolongation or a 50%

drop in amplitude of the wave V. This criteria is somewhat arbitrary, and hearing preservation is possible even with a transient complete loss of wave V. Alternatively, smaller latency prolongations and amplitude decrements have been associated with postoperative hearing changes. This appears to be related to the underlying pathology, with patients undergoing resection of acoustic neuromas more susceptible for smaller changes than those undergoing microvascular decompression surgeries. {James, 2005 #51} Complete loss of wave V, even when it does not resolve by the end of surgery, is compatible with preserved hearing. This may be due to temporal dispersion without conduction block in the auditory pathway or because hearing pathways other than those measured by BAEP continue to persist. {Harner, 1996 #53}

Changes in BAEPs during surgery can occur due to technical problems, physiologic mechanisms, or injury to the auditory system. Technical problem can occur due to problems with the recording or stimulating electrodes, kinking of tubing delivering acoustic stimuli, equipment malfunction, or operator error. Physiologic changes include changes in temperature and blood pressure. A decrease in either can cause latency prolongation and amplitude decrement of the BAEP.

There are several ways in which the auditory system can be damaged during surgery. Compression, traction, thermal injury, and ischemia are the commonest causes. Many of these can be detected by BAEP changes, and if recognized early can prevent irreversible injury. Ischemia of the cochlea occurs from trauma to the internal auditory artery and causes a sudden loss of all BAEP waveforms. Injury to the distal auditory nerve will result in prolongation and decreased amplitude of wave I. Waves III and V will also be prolonged in a proportional manner, and the wave I-III and I-V interpeak latency will be stable. Severe injury will lead to loss of wave I and all subsequent waveforms. More proximal injury to the auditory nerve, such as may occur during acoustic neuroma or microvascular decompression surgery, results prolongation and decreased amplitude of waves III and V but not wave I. Consequently wave III and V absolute latency and I-III and I-V interpeak latencies are prolonged. Injuries to the brainstem can result in latency prolongation and decreased amplitude of both waves III and V if the lesion is near the cochlear nucleus. Lesions in the rostral pons affect only the wave V. {Legatt, 2002 #40}

#### E. Conclusions

BAEP monitoring is often used to limit injury to the auditory system during surgery. A latency prolongation of 1 ms and amplitude decrement of 50% are considered significant and should prompt an alert to the surgeon. Careful analysis of the change in BAEP waveforms may help localize the site of potential injury in the auditory system.