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Auditory Evoked Potentials: A Reliable Guide to Sedation Levels during General Anethesia

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Abstract: ***General anesthesia is the deliberate induction and maintenance of reversible unconsciousness, analgesia and areflexia. Anesthetics produce dose-dependent suppression of cognitive processing. Due to the use of neuromuscular blocking agents and also due to the inherent side effects of the anesthetics themselves, clinical signs of inadequate anesthesia, such as spontaneous movement or increase of blood pressure with surgical stimulation are suppressed. Techniques to reliably detect of states of inadequate anesthesia are, therefore, highly desirable. The auditory evoked potential index (AEPidx) provides a reliable and single numerical variable to obtain real time data of state of consciousness that is superior to BIS monitoring. This research paper helps in accessing that auditory evoked potential as a reliable guide to sedation levels during general anesthesia***

Keywords: Auditory Evoked Potentials, Sedation, General Anaesthesia

1. Introduction

General anesthesia is the deliberate induction and maintenance of reversible unconsciousness , analgesia and areflexia. Anesthetics produce dose-dependent suppression of cognitive processing. Due to the use of neuromuscular blocking agents and also due to the inherent side effects of the anesthetics themselves, clinical signs of inadequate anesthesia, such as spontaneous movement or increase of blood pressure with surgical stimulation are suppressed. Techniques to reliably detect of states of inadequate anesthesia are, therefore, highly desirable.

Monitoring the depth of sedation is difficult and usually based on clinical assessments of patients' responses. These are subjective and not standardized and carry the risk of unnecessary sedation and delays in recovery post procedure. An objective measurement of anesthetic depth remains a desirable but elusive goal in anesthesia. The use of processed derivatives of the EEG, the cerebral function monitor, fast Fourier transformation, aperiodic waveform analysis and changes in lower esophageal contractility have all been utilized for this purpose. They are all insufficiently discriminating at the interface between consciousness and unconsciousness. The most promising development towards this end has been the auditory evoked potential (AEP). It is more sensitive to specific changes in its early cortical components related to depth of anesthesia, independent of the anesthetic agent. (1, 2, 3, 4, 5, 6, 7)

Brainwave Monitoring for Depth of Anesthesia

EEG

This is a passive measure and a raw EEG is typically divided into 1024–2048 epochs of 80–150 ms, averaged and displayed on the computer screen. Amplitudes and latencies are measured manually off-line. This is acceptable in audiological studies where the data acquisition and processing time can be extended almost indefinitely. In anesthesia, however, it is inadequate, as the condition of the patient changes much more rapidly and a faster update is required. Evaluation of the EEG response to standardized external stimuli offers an alternative approach.

Evoked Potentials

Cortical function and responsiveness can be assessed using the long latency evoked potentials (EP), also referred to as event-related potentials (ERP). These potentials reflect both exogenous and endogenous components of the cortical response. Exogenous components appear after detection of a sensory stimulus, and endogenous components are related to cognitive processes, such as attention and memory.

An evoked potential (EP) or evoked response is an electrical potential in a specific pattern recorded from a specific part of the nervous system. EP is distinct from spontaneous potentials as detected by EEG, EMG, or other electro-physiologic recording method. EPs are useful for electrodiagnosis and monitoring disease, drug-related sensory dysfunction and intraoperative monitoring of sensory pathway integrity.

Sensory evoked potentials can be visual, auditory or somatosensory.

Brainstem auditory evoked potentials (BAEPs) are the electrical signals or auditory evoked potentials produced by the nervous system within the first 10 ms following a transient acoustic stimulus in the form of a series of clicks. These are used for neurodiagnostic testing, intraoperative monitoring, hearing screening/ audiometry, and neurophysiological research. EPS of cortical origin are more prone to modification by anesthetics than BAEPs and subcortical portions of SSEPs. All volatile anesthetics increase cortical latency and decrease cortical amplitude.

The Auditory Evoked Potential

The auditory evoked potential response was first described by Jewett and Williston in 1971. (8) The auditory evoked potential is generated in the cochlea, goes through the cochlear nerve, through the cochlear nucleus, superior olivary complex and lateral lemniscus to the inferior colliculus of the brain, on to the medial geniculate body and finally to the cortex. (Fig 1)

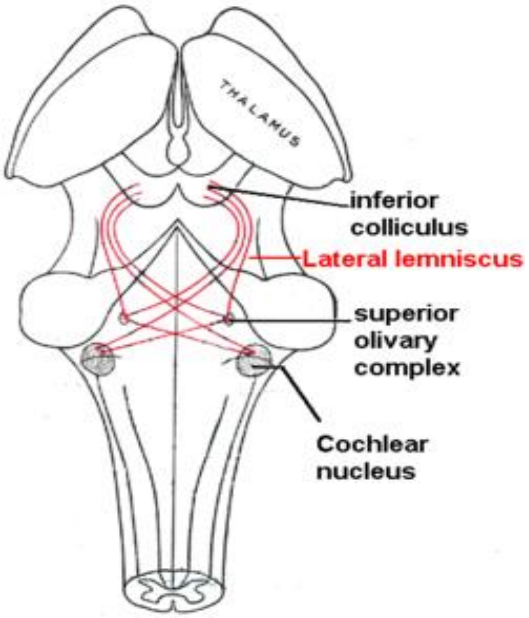

Figure 1: Anatomy of the auditory pathway

The AEP is extracted from ongoing electrical activity in the brain and recorded via electrodes placed on the scalp. Fifteen distinct components can be identified in the scalp recorded average evoked potential to an abrupt auditory stimulus. The early short latency components (I–VI) occur in the first 8 msec after a stimulus. Waves I through III are generated by the auditory branch of the VIIIth cranial nerve and waves IV and V are generated by the upper brainstem. Wave I originates from the dendrites of the auditory nerve fibres, wave II from the cochlear nucleus, III showing activity in the superior olivary complex and wave IV–V associated with the lateral lemniscus. The middle latency components (N_o, P_o, N_a, P_a, N_b) occur between 8 and 50 msec after the stimulus, and represent activation of both auditory thalamus and cortex. These are prone to contamination by concurrent scalp muscle reflex potentials. The longer latency components (P_1, N_1, P_2, N_2) occurring between 50 and 300 msec after the stimulus are maximally recorded over the fronto-central scalp regions and represent widespread activation of frontal cortex. (9) These potentials generally have an amplitude of less than 2 microV. (Fig 2).

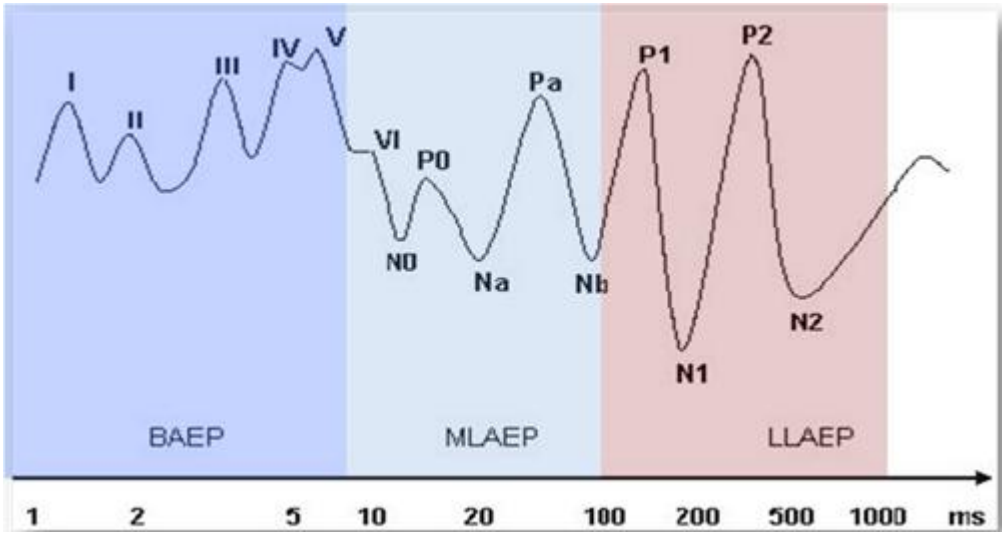

Figure 2: Short latency response (< 10 ms), Middle latency response (10-100 ms), Long latency response (> 100 ms)

Measuring AEP

AEP is dependent on external factors, it is considered an exogenous response. Auditory evoked potentials (AEP) are the response of the auditory pathway to sound stimuli. An AEP is calculated by repeatedly applying clicks with a duration of 100 μs, 90 dB (SPL) and a repetition rate of 9.3 Hz, presented binaurally via shielded earphones. Each AEP epoch consisted of 1000 stimuli. The EEG periods that immediately follow each stimulus is averaged, thus eliminating artifacts and the non-stimulus-related portion of the EEG, thus preserving the specific evoked potentials. These vertex-positive segments of the potentials, numbered I to V according to the anatomical area of its origin and the time elapsed since the stimulus, are interpreted considering the following:

(a) The wave amplitude, which indicates the number of neurons firing
(b) Latency of the wave, which indicates the speed of transmission
(c) Interpeak latency, which shows the time between peaks
(d) The interaural latency, which shows the difference in wave latency between the 2 ears.

A single numerical parameter extracted from the auditory evoked potentials is required, which can provide an estimate of anesthetic depth in a simple and reliable manner. Ideally, this parameter should be easy to extract, reliable, not computationally intensive and updated in short, clinically useful intervals. When patients lose consciousness, the amplitudes of the AEP peaks are reduced and their latencies increase. These changes occurred almost simultaneously and in the same direction in all patients. Consequently, a measurement reflecting these changes can be of value.

Short-latency AEPs have achieved the greatest clinical utility because they are relatively easy to record and their waveforms and latencies are highly consistent across normal subjects. They are unaffected by the subject's degree of attention to the stimuli and are almost identical in the waking and sleeping states, aside from minor differences related to changes in body temperature. (10, 11) Sedation and a typical surgical level of anesthesia produces only minor alterations in BAEPs.

The Middle-latency auditory evoked potentials (MLAEP) are measured 40 and 60 ms after stimulation and represents neural activity within the thalamus and primary auditory cortex. It is elicited with a bilateral click stimulus of 70 dB intensity and 2 ms duration and used to quantify the pharmacodynamic action of anesthetic drugs. (12)

Only AEP index demonstrates a significant difference (P,0.05) between all mean values 1 minute before and after recovery of consciousness and is superior to bispectral index (BIS). The auditory evoked potential index but not the BIS, can discriminate slight changes of consciousness during light sedation. (13) Changes in auditory evoked potential (AEP) amplitudes and latencies correlate well with depth of anaesthesia. These changes are similar for equipotent doses of enflurane, halothane, isoflurane, etomidate, althesin and propofol and are partially reversed by surgical stimulation. (14-23)

Newer devices process the raw EEG, acquire the AEP and extract an auditory evoked potential index (AEPidx) in real time that reflects latencies and amplitudes of the AEP. The AEPidx is a mathematical derivative reflecting the morphology of the AEP and calculated as the sum of the square root of the absolute difference between every two successive 0.56 msec segments of the AEP waveform. The AEPidx follows all changes in both amplitudes and latencies of the AEP consistently and has three main advantages over the conventional methods of describing the AEP in terms of latencies and amplitudes:

1) It is easy to calculate;
2) The calculation can be performed in real time;
3) It provides a single numerical variable that describes the underlying morphology of the AEP

The AEPidx extracted from the AEP using a proprietary data compression algorithm shows changes according to the patient's state. A value of 80 is associated with wakefulness and a value <50 with unconsciousness. It has a clear advantage over the Nb latency in the determination of awareness, since it can be extracted from the AEP in a rapid and reproducible fashion. The AEPidx is , however, not perfect, as it is affected by muscle and movement artifacts, diathermy and other electrical operating theatre interference. However, these sources of potential error are eliminated by the rigorous artifact rejection algorithms and the low-pass filtering to which the signals are subjected. (24,25)

The first commercial monitor based on AEP was introduced by Danmeter in 2001. This was followed by a new version of the monitor AEP-Monitor/2, which is not only based on AEP, but includes also spectral EEG parameters. The monitor uses autoregressive models with exogenous input (ARX) to detect the AEP. The ARX were used because the method enables fast monitoring of responses in the frequency range 25–65 Hz.

AED and Brain Death

In those with all the clinical criteria for brain death 65.8% do not show any response, 3.42% show a type I wave, which is unilateral in 26.3% and bilateral in the other 7.9%. Types II to VII waves are never seen. Type I waves show increasing latency. Two facts might explain the progressive delay and disappearance of wave I in brain-dead patients: a progressive hypoxic-ischaemic dysfunction of the cochlea and eighth nerve plus hypothermia, often present in brain-dead patients. Thus AED forms a non invasive electro physiologic technique for the diagnosis of brain death. Evoked potential is useful in confirming the diagnosis of brain death in infants and in children as well as in adults. The test can be performed at bedside without interfering with patient care, and results are similar to those obtained in adult patients. Flattening of the EEG requires more time than achieving compatible evoked-potential responses. (26, 27, 28, 29)

2. Conclusions

Long-latency AEPs are affected profoundly by the degree to which the subject is attending to the stimuli and analyzing stimulus features and useful as probes of cognitive processes. Their variability, as well as uncertainty about the precise identity of their cortical generators, limits their utility for neurologic diagnosis. Middle-latency AEPs are small and prone to contamination by myogenic signals. Their subject to subject variability limits their clinical application. Both middle- and long-latency AEPs are affected prominently by surgical anesthesia.

Short-latency AEPs have achieved the greatest clinical utility because they are relatively easy to record and their waveforms and latencies are highly consistent across normal subjects. They are unaffected by the subject's degree of attention to the stimuli and are almost identical in the waking and sleeping states. The auditory evoked potential index (AEPidx) provides a reliable and single numerical variable to obtain real time data of state of consciousness that is superior to BIS monitoring.

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