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11

Auditory evoked potentials

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This chapter will focus on the two auditory evoked potentials (AEP) most commonly used to assess the effects of general anesthetics on the brain, the auditory middle latency response (AMLR) and the 40 Hz auditory steady-state response (40 Hz-ASSR). We will review their physiological basis, the recording methodology, the effects of general anesthetics, their ability to track changes in level of consciousness and their clinical applications. Because of space constraints, this review will be limited to human studies.

Key words: brain; general anesthetics; consciousness; unintentional awareness; depth of anesthesia.

INTRODUCTION

Auditory evoked potentials (AEPs) are changes of the electrical activity of the brain (i.e. the electroencephalogram—EEG), produced by auditory stimuli. AEPs consist of positive and negative deflections (or waves) that follow the stimulus in a time-locked manner. AEP are produced by changes of electrical potential across neuronal membranes in the auditory system. The ability to record the AEP from distant sites on the scalp depends on four factors:[1] (1) the *number* of cells activated by the stimulus; (2) the degree of *synchronization* of this activation (the more synchronous the activation, the larger the response); (3) the geometry of the structure activated (depending on the arrangement of cells, the microscopic dipoles produced by the activation of each neuron may summate or cancel each other); (4) the ability of surrounding tissues (bone, muscle, CSF, glia) to conduct electricity.[1] General anesthetics primarily affect factors one and two and may indirectly influence factor three.

AEPs are much smaller than the EEG, and are thus not visible on the raw EEG. The circular waves produced by dropping a stone in quiet water provide a useful analogy. Dropping the stone in the sea will cause the same waves, but they will be hidden by the random fluctuations of the sea. The most common method to isolate the AEP from

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background EEG is averaging the EEG responses to multiple identical stimuli. The AEP will remain constant for all stimuli (because it is time-locked) while the background noise will vary and thus be reduced by averaging.

AEPs are classified as either *transient* or *steady-state*[1] (Figure 1). Transient AEPs are seen when rate of stimulus delivery is slow enough for the response to wear off before the next stimulus. Steady-state AEPs are seen when rate of stimulus delivery is fast enough to cause overlap of the individual transient responses. They consist of sinusoidal waveforms having the same frequency of that of stimulus delivery. To use again the stone in water analogy, with transient responses, one waits for the waves (AEP) to disappear before dropping a second stone (delivering the next stimulus). For steady-state responses, the stones are dropped at a rate fast enough for the waves to overlap. Transient responses are characterized by their latency (time between stimulus onset and the AEP) and by their amplitude. Steady-state responses are characterized by their phase (by reference to a one-cycle sine wave) and amplitude. The steady-state response evoked by stimuli delivered at rates near 40/second (and accordingly named 40 Hz auditory steady-state response (40 Hz ASSR)) (Figure 1) has been used extensively to assess anesthetic effect.

Transient responses are classified according to their latency as fast (6–10 millisecond), middle (10–50 millisecond), slow (50–250 millisecond), and late (>250 millisecond) responses. The auditory brainstem response (ABR) is a fast

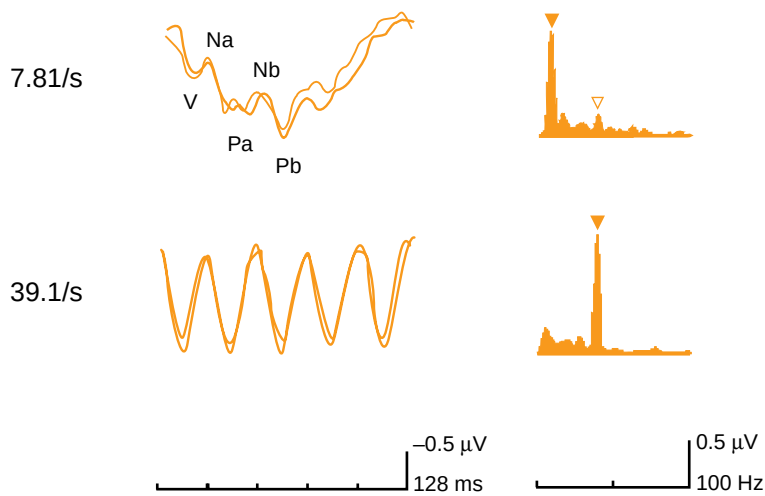

Figure 1. Transient (AMLR-top row) and steady (40 Hz ASSR-lower row) state responses. Evoked potentials were recorded in response to 500 Hz tone pips (10 millisecond duration; 65 dB above hearing threshold). The recordings were obtained between the vertex and the right mastoid with negativity at the vertex plotted upward. On the left are the evoked potentials recorded over a sweep of 128 millisecond when the tone pips were presented at rates of one or five times per sweep. Each tracing represents the average of 1000 responses. At the slow rate, several components (Na, Pa, Nb, Pb) of the AMLR are visible. At the faster rate, the 40 Hz ASSR occurs with a phase at zero-time of 142°. On the right are the amplitude spectra for the average evoked potentials. For the AMLR, most of the energy is at the rate of stimulation (closed triangle), but there is also some activity at 39 Hz (open triangle). For the ASSR, the 39 Hz region of the spectrum is markedly enhanced (closed triangle). Modified with permission from Ref. [79].