Neurophysiological meaning of the similarities between sleep spindles, k-complexes, and anesthesia bursts

Significado neurofisiológico de las similitudes entre los husos de sueño, complejos-k y las descargas físicas durante anestesia

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ABSTRACT

Sleep and general anesthesia have been described as distinct states. However, several studies have found common neural circuitries, and shared mechanisms between these two states. Sleep spindles and K-complexes can be evoked by external stimulation during NREM sleep. We recorded cortical burst activity synchronized to auditory external stimulation in isoflurane-anesthetized rats. We hypothesize that sleep spindles, K-complexes, and bursts evoked by external stimulation might have a common neuronal generator and perhaps similar neurophysiological meaning.

Key words: Auditory processing, gas anesthesia, burst suppression.

RESUMEN

El Sueño y la anestesia general han sido descritos como estados diferentes. Sin embargo, varios estudios han encontrado circuitos neurales comunes y mecanismos compartidos entre estos dos estados. Los usos de sueño y los complejos-K pueden ser evocados por estimulación externa durante sueño tranquilo. Nosotros registramos descargas fásicas de alta amplitud sincronizadas con estimulación auditiva externa en ratas anestesiadas con isoflurano. Nuestra hipótesis es que los husos de sueño, los complejos-K y las descargas fásicas de alta amplitud evocadas con estimulación externa podrían tener un generador neuronal común y quizá un significado neurofisiológico similar.

Texto

Several studies have found physiological differences between natural sleep and anesthesia[1]. Unconsciousness being readily reversible during sleep, but irreversible under anesthesia makes these states distinct[2]. Also, somatosensory evoked potentials (SEP) recorded over the skull show specific shape and differential temporal patterns during sleep and anesthesia[3]. However, recent findings suggest that brain nuclei involved in sleep control are quite important in anesthesia mechanisms. It is likely that some neural networks used to keeping us awake are necessary to wake us up from anesthesia. Additionally, anesthetics can cause sleep with direct administration into brain nuclei known to regulate sleep, and endogenous neuromodulators known to regulate sleep also alter anesthetic action[2]. Studies have shown experimental evidence of a relationship between the degree of prior sleep deprivation and the anesthesia potency, and also about the dissipative effect of anesthesia on sleep debt[4]. All these findings highlight more similarities between sleep and anesthesia than earlier investigation have considered.

The electroencephalogram (EEG) shows characteristic temporal patterns under different anesthetic conditions. A burst suppression pattern appears during deep isoflurane anesthesia, where high amplitude bursts are followed by periods of nearly silent (EEG) [5.]

Spindle oscillations ranging between 12 to 14 Hz recur periodically in the thalamus and cortex during sleep[6,7]. The hyperpolarization of thalamocortical neurons caused by the recurrent inhibitory circuit in the reticular thalamus induces spindles over most of the cortex[8]. Sleep spindles might be the electrical result of inhibitory neuronal firing gating synaptic transmission through the thalamus to avoid sleep disruption[7]. K-complex is a negative-positive complex with a latency ranging from 100 to 250 ms post-stimulus, which can be recorded from the human scalp in response to various external stimuli. In humans, k -complexes occur in stages 2, 3 and 4 of nrem sleep[9].

We found spontaneous and stimulus-evoked bursts during deep isoflurane anesthesia in rats. The burst activity during anesthesia contains waves of high amplitude and a predominant 10 Hz frequency (Fig. 1). The burst activity shares at least two important characteristics with sleep spindles and k-complexes: it can be evoked by external stimulation during unconsciousness states, and has a predominant 10 Hz frequency waves. Since the brain retains the ability to respond to external stimuli during deep anesthesia, in a form of bursts, we hypothesize that there is a common neuronal generator and perhaps similar neurophysiological meaning for sleep spindles, k-complexes, and anesthesia bursts. If so, burst activity during deep anesthesia might be a potential experimental model to study somatosensory processing during sleep.

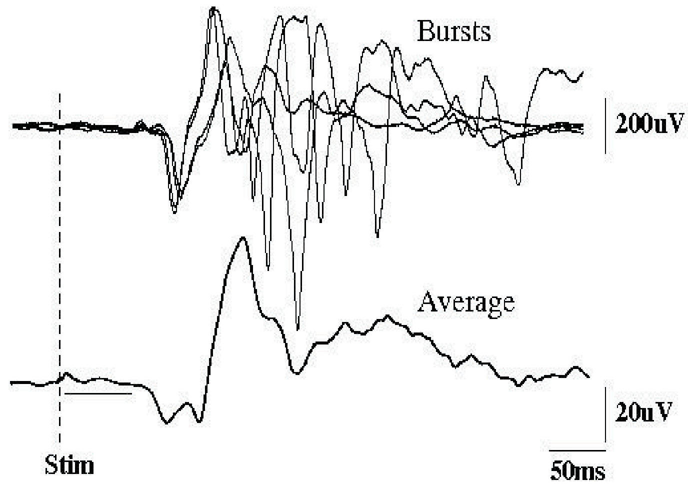

Figure 1. Burst shape. The superimposed traces in the top panel show examples of bursts at 2% [isof]. The bottom trace is the average of evoked burst responses (n=552) at 2% [isof]. During anesthetized conditions a high-amplitude response appears 250 ms after the auditory stimulus. The appearance of individual bursts resembles the shape of a sleep spindle, while the average of multiple bursts looks like a K-complex.

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