Evoked Metabolic Responses Differ Significantly During Sleep Stages

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In order to investigate the functions and neural consequences of sleep on the brain, we measured an index of brain metabolism through scattered light optical techniques. We hypothesize that at least one component of sleep may be initiated by a metabolic demand and a lack of adequate resources to supply that demand. To study brain activity during different states, we characterized the electrical response and scattered light signals from the rat cortex following whisker stimulation during wake, quiet sleep, and REM sleep. We illuminated the rat whisker barrel cortex with 660 nm wavelength light while stimulating the barrels with a burst of 5 whisker twitches (10 Hz). This stimulus was applied at random intervals between 2 and 13 seconds. In order to achieve adequate sleep under restrained conditions, the rat was sleep deprived for 8 hours prior to the recording. The evoked optical signal derived from the hemodynamic response showed an initial dip in local hemoglobin concentration after 0.75 s, an overcompensation at 2.5 s, which may be related to a blood oxygen level dependent response, followed by a long lasting undershoot. During quiet sleep, the evoked optical signal maintained the same general shape as the wakeful signal but manifested a significantly higher amplitude, coinciding with the amplitude increase in the electrical evoked responses. During REM sleep, the EEG signal was nearly identical to the wake signals, but the evoked optical signal demonstrated a delayed phase shift and smaller amplitude. Our results show that metabolism at a local level is unique between REM and waking. Additionally, quiet sleep produced a larger metabolic response perhaps due to a larger recruitment of blood during that state or a lower initial supply level reaching the same ultimate peak as wake. If one of the purposes of quiet sleep is to restore tissue metabolites while in a quiescent state, then we might expect a large influx of blood during activation if the vasculature were more compliant during that state.