Novel characterization of an architecturally distinct sleep stage and its implications for recovery from the minimally conscious state

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Motivation

• An estimated 41% of patients with Disorders of Consciousness (DOC) who demonstrate awareness are misdiagnosed as being in the vegetative state (Cajochen et al., 2009).

• The central thalamus has been proposed to play a key role in the maintenance of synchronous activity across frontostriatal systems during wakeful states following severe brain injuries (Cajochen et al., 2010).

• Central thalamic deep brain stimulation (CT-DBS) may drive frontostriatal activity in the widely deafferented brain to facilitate behavioral recovery (Cajochen et al., 2011).

• Cortical firing rates during sleep have been shown to be increased after sustained wakefulness or activity during the day (Cajochen et al., 2010).

These considerations motivated examination of longitudinal changes in thalamo-cortically driven elements of sleep electrophysiology in a CT-DBS DOC patient to evaluate the potential impact of daytime driving of frontostriatal systems.

Patient History

• A 45 year old man who suffered a severe traumatic brain injury in a motor vehicle accident at the age of 17.

• Unable to communicate or respond to spoken commands since the time of injury.

• Emotional reactivity to humor or scatological speech despite no consistent purposeful movements of head, eyes, or limbs.

• One of three subjects in a fixed-effects study of CT-DBS patients in the minimally conscious state (MCS) (Jagadeesh et al., 2011).

• Coma recovery scale-Revised (CRS-R) scores remained consistent with MCS diagnosis across evaluations (McKenzie et al., 2010).

Methods

SWS power in the spindles frequency range over time

Stage 2 and SWS power spectra pre-, during, and post-CT-DBS

Mean spectral power in the 8.5-16 Hz spindle frequency range during SWS demonstrates a significant reduction from T1 to T2, concurrent with onset of CT-DBS. This reduction remains significant at T4, suggesting normalized widening of SWS architecture with CT-DBS.

Stage 2 SWS

Power spectra calculated from stage 2 and SWS at T1, T4, and T5, corresponding to pre-, active, and post CT-DBS conditions. Spectra show a bilateral increase in stage 2 peak frequency in the spindle range from T1 to T4, followed by a complete loss of the spindle peak at T5. During SWS, spectra show an aberrant intrusion of power in the spindle range at T1 that is attenuated at T4 and returns to baseline power at T5.

Conclusions

Daytime CT-DBS may induce consistent, frontal driven changes in sleep electrophysiology during stage 2 and SWS.

A distinct electrophysiological stage during sleep, termed here the “mixed state”, may indicate sub-threshold forebrain activation.

Specifically, the mixed state may result from an inability of neuronal structures to drive the network from thalamically driven stage 2 into cortical-driven SWS.

We hypothesize that:
1. If present, the mixed state is indicative of partial recovery of cortical activation linked to increased daytime arousal and behavioral engagement.

2. Should consistently yield to normal SWS.