Crosstalk of cortical and cardiac slow oscillations in humans and mice

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Background: Vigilance states are defined by characteristic brain oscillations. In contrast, physiological markers of vigilance states in other organs are rarely investigated. Therefore, the relationship between state-dependent brain oscillations and body physiology remains poorly understood. Heart rate variability (HRV) is a marker of parasympathetic activity. This study aimed to analyse the interaction of HRV and sleep-related brain oscillations in mice and humans to investigate a putative crosstalk between brain and body rhythms.

Methods: We performed (1) undisturbed 24-h recordings of EEG, EMG and 16-channel silicon probes in adult, male C57NL/6 mice (n=4) and (2) overnight polysomnography in 45 human participants (22 male, 23 female; mean age 37 years). ECG R-peaks in mice were identified from the EMG signal, in humans from a Lead II Einthoven configuration using Kubios HRV.

Results: In both mice and humans, we found a significantly higher heart rate, lower mean square of successive differences (RMSSD) and lower high frequency component of heart rate variability (HF-HRV) during NREM sleep compared to REM sleep (Students t-test, both $p<0.05$) indicating that heart rhythms are dependent on vigilance state. To investigate oscillatory patterns of HRV, we next investigated the time course of interbeat intervals (IBIs). Fast Fourier transform revealed a prominent peak at 0.3 Hz in mice and 0.35 Hz in humans, suggesting a presence of a slow oscillation in the HRV. Importantly, we found a high phase locking value between IBIs and the respective-frequency component in the cortical LFP during NREM sleep, which in the 0.16-1.25 Hz range was on average 0.38 in mice and 0.29 in humans ($p<0.05$, permutation test), suggesting a temporal coupling of slow oscillations in cortical activity and HRV during sleep.

Conclusions: This study confirms prominent state-dependency of several characteristics of cardiac activity in both mice and humans. We make the observation of a prominent slow oscillation in the heart inter-beat intervals. Intriguingly, the periodicity in cardiac electrical activity during NREM sleep correlated with the slow oscillation in the cortex. Our data identifies a previously unnoticed crosstalk between cortical and cardiac rhythms, which indicates a previously overlooked synchronisation of brain and heart oscillations during sleep.