Effect of Vigilance State on the Spatial Profile of Cortical High Frequency Oscillations

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7a

Rationale: There is broadening consensus that the spatial pattern of cortical high frequency oscillations (HFOs) is strongly indicative of the ictogenic zone in individuals with epilepsy. Not as clear is what constitutes a good sample for diagnostic use: When to record and for how long; how many HFOs; and what kind? HFO occurrence can vary greatly with vigilance state. A common heuristic is to record 10 min of the electrocorticogram (ECoG) during slow wave sleep, in which HFOs are more frequent, and map relatively "active" contacts to the epileptogenic zone. But whether this rule merely produces an adequate sample or whether the pattern of HFO activity in slow wave sleep is fundamentally different from that of other vigilance states is an open question that motivates the present study.

Methods: With IRB approval from UT Southwestern Medical Center, seizure-free overnight ECoGs (8-12 h each, 1-2 kHz sampling) were analyzed from five patients with focal epilepsy. The Staba algorithm was used to identfy HFOs, mainly in the ripple band (80-250 Hz), from all bipolar ECoGs. Power estimates in 30-s epochs of scalp EEG in different spectral bands (0.5-2, 2-4, 4-8, 8-13, 13-30, and 30-55 Hz) were clustered into vigilance states S1, S2, S3, and S4 from wakefulness to slow wave sleep. HFOs were counted for epochs sorted by vigilance state. Each ECoG was divided into 20-min windows in which the proportion of HFO-containing epochs (pHFO) was computed. The modal vigilance state in the constituent epochs was assigned to each window. The result was a set of windows characterized by vigilance state and spatial pHFO profile. Spearman's rank correlation r was computed between pHFO profiles of windows in different states and compared with r values between pHFO profiles of windows in the same state. This is to determine whether the inter-correlation between pHFO profiles of different states is no worse than the "self-correlation" between sample profiles from the same state: i.e., whether pHFO profile varies with vigilance state allowing for sampling error.

Results: pHFO varied significantly with vigilance state ($p < 0.01$) and increased in the mean from S1 to S4. The pHFO profile was most stable in S4, with a high mean self-correlation ($r = 0.94$) that steadily decreased to 0.91 in S3, 0.86 in S2, and 0.85 in S1. The mean inter-correlation between pHFO profiles in S4 and the other states was significantly lower than the self-correlation in S4, but almost identical to the self-correlation in each of those states.

Conclusions: We have examined whether sampling HFOs in slow wave sleep merely increases the odds of detecting them or whether the spatial distribution of HFO activity is fundamentally different in this state. The data suggest that the profile observed in slow wave sleep is not necessarily different from those from other vigilance states. However, a sample from slow wave sleep may be more consistent and reliable due to the larger average yield, lower likelihood of signal artifacts, and relative certainty with which vigilance state can be determined. The results may not apply to fast ripples due to the low sampling rate used here.