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Effects of the physiological parameter evolution on the dynamics of tonic-clonic seizure

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The temporal and spectral characteristics of tonic-clonic seizures are investigated by using a neural field model of the corticothalamic system in the presence of a temporally varying connection strength between the cerebral cortex and thalamus. Increasing connection strength drives the system into 10 Hz seizure oscillations once a threshold is passed and a subcritical Hopf bifurcation occurs.

In this study, the spectral and temporal characteristics of tonic-clonic seizures are explored as functions of the relevant properties of physiological connection strengths, such as maximum connection strength, time above threshold, and the rate at which the connection strength increases or decreases (ramp rate). Dynamical analysis shows that the seizure onset time decreases with the maximum connection strength and time above threshold, but increases with the ramp rate. Seizure offset time and duration increase with maximum connection strength, time above threshold, and rate of change. Spectral analysis reveals that the power of nonlinear harmonics and the duration of the oscillations increase as the maximum connection strength and the time above threshold increase. A secondary limit cycle, termed a saddle cycle in previous studies, is also seen in this study. A detailed analysis of the saddle cycle oscillations shows that these oscillations become more prominent and robust with maximum connection strength and rate of change of the ramp. However, for a small ramp rate, the system does not exhibit any saddle cycle oscillations. We also find that if the time above the threshold is too small and the ramp rate is too large, the system does not reach to the larger limit cycle attractor of 10 Hz oscillation, and only exhibits the saddle cycle oscillations. It is also seen that the times to reach the saturated large amplitude limit-cycle seizure oscillation from both the instability threshold and from the end of the saddle cycle oscillations are inversely proportional to the square root of the ramp rate, as is the time to reach the seizure offset from the bifurcation from the saturated limit cycle oscillations.

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