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Stimulus-induced transitions between spike-wave discharges and spindles with the modulation of thalamic reticular nucleus. (English) Zbl 1402.92082

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Summary: It is believed that thalamic reticular nucleus (TRN) controls spindles and spike-wave discharges (SWD) in seizure or sleeping processes. The dynamical mechanisms of spatiotemporal evolutions between these two types of activity, however, are not well understood. In light of this, we first use a single-compartment thalamocortical neural field model to investigate the effects of TRN on occurrence of SWD and its transition. Results show that the increasing inhibition from TRN to specific relay nuclei (SRN) can lead to the transition of system from SWD to slow-wave oscillation. Specially, it is shown that stimulations applied in the cortical neuronal populations can also initiate the SWD and slow-wave oscillation from the resting states under the typical inhibitory intensity from TRN to SRN. Then, we expand into a 3-compartment coupled thalamocortical model network in linear and circular structures, respectively, to explore the spatiotemporal evolutions of wave states in different compartments. The main results are: (i) for the open-ended model network, SWD induced by stimulus in the first compartment can be transformed into sleep-like slow UP-DOWN and spindle states as it propagates into the downstream compartments; (ii) for the close-ended model network, weak stimulations performed in the first compartment can result in the consistent experimentally observed spindle oscillations in all three compartments; in contrast, stronger periodic single-pulse stimulations applied in the first compartment can induce periodic transitions between SWD and spindle oscillations. Detailed investigations reveal that multi-attractor coexistence mechanism composed of SWD, spindles and background state underlies these state evolutions. What's more, in order to demonstrate the state evolution stability with respect to the topological structures of neural network, we further expand the 3-compartment coupled network into 10-compartment coupled one, with linear and circular structures, and nearest-neighbor (NN) coupled network as well as its realization of small-world (SW) topology via random rewiring, respectively. Interestingly, for the cases of linear and circular connetivities, qualitatively similar results were obtained in addition to the more irregularity of firings. However, SWD can be eventually transformed into the consistent low-amplitude oscillations for both NN and SW networks. In particular, SWD evolves into the slow spindling oscillations and background tonic oscillations within the NN and SW network, respectively. Our modeling and simulation studies highlight the effect of network topology in the evolutions of SWD and spindling oscillations, which provides new insights into the mechanisms of cortical seizures development.

MSC:

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Keywords:

spike-wave discharges; UP-DOWN state; spindles; thalamic reticular nucleus; cortex; stimulation

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