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3D Modeling of Glutamate Convectional Diffusion in A Functional Synaptic Cleft

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ABSTRACT

Synaptic plasticity (SP)lays at the basis of cognition, memory and learning. Glutamatergic neurotransmission with its adaptable biological properties plays an essential role in SP formation. The synaptic cleft area expands at highly active synapses allowing more neurotransmitter release sites at the presynaptic active zone and wider postsynaptic membrane area for receptor proteins. Adjacent astrocyte extends its leaflet to envelope the cleft, provides a sufficient amount of glutamate transporters and ensures excitotoxic (high extracellular glutamate level) conditions avoiding which is in attendance on many neurodegenerative diseases and brain injury. An algorithm for creating a synaptic cleft digital phantom was proposed using COMSOL Multiphysics in accordance with earlier isolated synapse models. 3D phantoms kit of functional glutamatergic synapses depictures considered biological structures at different stages (formation, mature state, elimination).The kit poses validated sizes and distances between pre- and postsynaptic endings, precise localization of vesicular partial release, extending astrocytic leaflets cradling and is suitable for glutamate convectional reaction–diffusion modeling. Functional parameters of glutamate release from varied number of vesicles with distinct localization were defined. Convectional diffusion of neurotransmitter with its reuptake by glutamate transporters was evaluated in the interstitial fluid area. The variations in glutamate levels observed at functional synapses allow for a more detailed understanding of intricate biological mechanisms and can help forecast potential triggers for excitotoxicity.

Keywords: synaptic cleft, glutamate diffusion, 3D modelling

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