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Effects of Ih and TASK-like shunting current on dendritic impedance in layer 5 pyramidal-tract neurons

Pyramidal neurons in neocortex have complex input-output relationships that depend on their morphologies, ion channel distributions, and the nature of their inputs, but which cannot be replicated by simple integrate-and-fire models. The impedance properties of their dendritic arbors, such as resonance and phase shift, shape neuronal responses to synaptic inputs and provide intraneuronal functional maps reflecting their intrinsic dynamics and excitability. Experimental studies of dendritic impedance have shown that neocortical pyramidal tract neurons exhibit distance-dependent changes in resonance and impedance phase with respect to the soma. We therefore investigated how well several biophysically-detailed multi-compartment models of neocortical layer 5 pyramidal tract neurons reproduce the location-dependent impedance profiles observed experimentally. Each model tested here exhibited location-dependent impedance profiles, but most captured either the observed impedance amplitude or phase, not both. The only model that captured features from both incorporates HCN channels and a shunting current, like that produced by Twik-related acid-sensitive K+(TASK) channels. TASK-like channel density in this model was proportional to local HCN channel density. We found that while this shunting current alone is insufficient to produce resonance or realistic phase response, it modulates all features of dendritic impedance, including resonance frequencies, resonance strength, synchronous frequencies, and total inductive phase. We also explored how the interaction of HCN channel current (Ih) and a TASK-like shunting current shape synaptic potentials and produce degeneracy in dendritic impedance profiles, wherein different combinations of Ih and shunting current can produce the same impedance profile.

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