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How spatial cell properties shape Ca^{2+} signals

Ca^{2+} plays a major role in many physiological processes including muscle contraction and gene regulation. The versatility is achieved by a wide spectrum of Ca^{2+} signals ranging from fast local events to cell wide repetitive spiking and plateau responses. It is still a challenge to understand how cells generate reliable cellular signals with microscopic noisy Ca^{2+} release channels like IP_3Rs. We have recently shown in experiments that the microscopic fluctuations are carried on the level of the cell by the hierarchical organization of the Ca^{2+} pathway. Here we use our detailed modelling approach to analyze how Ca^{2+} signals depend on physiological parameters. The model describes individual release channels by Markov chains the states of which act as stochastic source terms in a reaction diffusion system representing the cell. This allows for following the Ca^{2+} signal from its local triggering event to the cell wide response. In extensive simulations we analyzed how the spatial properties shape Ca^{2+} signals. The simulations can quantitatively describe experiments in which Ca^{2+} diffusion is reduced by additional buffer. In further simulations, the temperature dependence of Ca^{2+} signals could be mapped to a change in the SERCA pump strength that determines the spatial coupling between release sites. All these modelled and experimental data are in addition analyzed and compared by a moment based approach that points to a functional robustness of the Ca^{2+} pathway.