Calibration of a Rescaled 0D Pacemaker-Bimembrane Model using Animal Experiments

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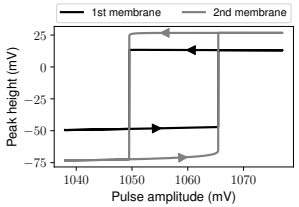
For certain heart conditions, such as bradycardia, patients may have an electrical stimulation device implanted in their heart. In pacemaker devices, a pulse generator delivers current into the myocardium for a short duration, depleting the battery by a known amount of energy. If an energy threshold is reached, the tissue is depolarized enough to trigger contraction. The device is said to *capture*. The threshold is closely related to the properties of the delivered stimulation (signal shape, pulse duration and amplitude), as well as the physiological characteristics of the implanted tissue. Studying this threshold helps to understand the biology involved and to extend the lifespan of pacemakers by more accurately adjusting them. Current numerical simulations do not generally include the coupling with devices. Furthermore, the mathematical definition of capture is not clearly defined yet. Modelling the system is complex because it must include both the stimulator's internal circuit and the electrode-tissue interface, which significantly affects the energy received by the tissue compared to that delivered by the stimulator.

We propose a new 0D model in the form of an ODE system that represents the coupling of a pacemaker with a rescaled two-membrane model through two contact models formed by a resistor in parallel with a capacitor. The developed model makes easier to compare simulated results to experimental data. Notably, the model reproduces the well-known dependence of the capture voltage threshold to the search strategy (ascending or descending voltages), observed for real pacemakers devices.



Hysteresis phenomenon for a fixed pulse width.

The model parameters, namely tissue properties and contact characteristics, are calibrated by comparing voltages measured between the pacemaker pins, using experimental data from ex-vivo sheep hearts. A prior Sobol global sensitivity analysis is performed on several markers of the signal, such as action potential duration (APD) or peak height to determine which parameters are identifiable.