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Discrete modeling of the sinoatrial node automaticity

Each heart cell — myocyte, communicates with the outside world by rapid changes displayed by ion channels. The membrane activity is tranduced directly to the neighboring cells establishing cell-to-cell communication. Because of these cell-to-cell connections the heart tissue is perfectly suited for modeling as a network of interacting units. Differences in intercellular connections are known to be crucial in forming physiologically different parts of the heart tissue.

The rhythmic contractions of the heart begin in the area of the cardiac tissue located on the right atrium called the sinoatrial node (SAN), see [1] for description of SAN physiology. Understanding of the SAN means to known how pacemaker cells maintain the final function, namely, successful pacemaking of the whole heart. Much difficulty in understanding is related to the arrangement of cells — how rather poorly connected cells can produce a signal self-consistent enough to drive the heart contraction. There are two basic approaches to the organization of the SAN cells: the mosaic and gradient models. The first one considers coexistence of two types of cells: nodal and atrial. The second approach assumes the gradual change of properties of individuals cells when moving from the central part of the SAN to its border. The main objective of our presentation is to find whether the SAN automaticity can result from heterogeneity of intercellular links.

The complex cellular processes involved in the SAN functioning are modeled by modified Greenberg-Hastings cellular automaton [2]. Since, there is a consensus that SAN cells are remains of the heart tissue from its very early stage of development, namely from the embryo, then the construction of intercellular connections rooted on stochastical square lattice is physiologically justified. Synchronic activation of the large parts of such network denotes adjusting of cellular excitations into a robust spiral wave [3].

Effects of perturbations in the topology of intercellular connections on periodicity of the system are considered. The focus is how thorough wrinkling of initially flat structure influences the regular beating. Since automaticity of the sinoatrial node relies on a single cell activity, cyclical properties of individual cells are studied. It appears that robust diversity of oscillations of a cell depends on both: properties of intrinsic cellular dynamics and the underlying topology of intercellular connections. Moderate nonuniformity of intercellular connections are found vital for the proper function of the sinoatrial node, namely, to respond effectively to the autonomic system control [4].

References

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