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Modeling Calcium Waves in an Anatomically Accurate Three-Dimensional Parotid Acinar Cell

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Abstract

We construct a model of calcium waves in a three-dimensional anatomically accurate parotid acinar cell, constructed from experimental data. Gradients of inositol trisphosphate receptor (IPR) density are imposed, with the IPR density being greater closer to the lumen, which has a branched structure, and inositol trisphosphate (IP_3) is produced only at the basal membrane. We show (1) that IP_3 equilibrates so quickly across the cell that it can be assumed to be spatially homogeneous; (2) spatial separation of the sites of IP_3 action and IP_3 production does not preclude the formation of stable oscillatory Ca^{2+} waves. However, these waves are not waves in the mathematical sense of a traveling wave with fixed profile. They result instead from a time delay between the Ca^{2+} rise in the apical and basal regions; (3) the ryanodine receptors serve to reinforce the Ca^{2+} wave, but are not necessary for the wave to exist; (4) a spatially-independent model is not sufficient to study saliva secretion, although a one-dimensional model might be sufficient. Our results here form the first stages of the construction of a multiscale and multicellular model of saliva secretion in an entire acinus.

Keywords: Saliva secretion, Inositol Trisphosphate Receptor, Ryanodine Receptor, Calcium oscillations, Multiscale modeling

1. Introduction

The primary role of salivary gland acinar cells is to secrete saliva, the lack of which causes a host of severe medical difficulties [1, 2]. Thus, an understanding of the mechanisms underlying saliva secretion are vital for the understanding of oral health. In every kind of salivary acinar cell, saliva secretion is controlled by the concentration of cytosolic Ca^{2+} [3]. Agonist stimulation (by, say,

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