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Calcium waves, potassium channels and their role in a mathematical model of saliva secretion

Abstract

The quality of life for millions of Americans is adversely affected by salivary gland dysfunction. It is estimated that up to 20% of adults in the US will suffer from xerostomia, a condition where not enough saliva is produced. The parotid gland is the largest of the salivary glands responsible for producing watery serous fluid.

We construct a mathematical model of the parotid acinar cell with the aim of investigating how spatial calcium waves and the distribution of potassium channels affect saliva production. The salivation process is initiated by calcium signals acting on calcium dependent potassium and chloride channels. The opening of these channels facilitates the movement of chloride ions into the lumen which water follows by osmosis. Once in the lumen the water is transported down the parotid duct to the mouth.

We use recent results into both the release of calcium from internal stores via the inositol (1,4,5)-trisphosphate receptor (IP_3R) and IP_3 dynamics to create a physiologically realistic calcium model. Calcium oscillations are the result of calcium feedback on IP_3 degradation. Our calcium model is able to recreate important experimentally observed behaviours seen in parotid acinar cells. We formulate an equivalent electrical circuit diagram for the movement of ions responsible for water flow. This electrical representation enables us to calculate and include distinct apical and basal membrane potentials to the model. We show that maximum saliva production occurs when a small amount of potassium conductance is located at the apical membrane, with the majority in the basal membrane. The maximum fluid output is found to coincide with a minimum in the apical membrane potential.