Dielectric Breakdown of Cell Membranes

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The term electrical breakdown of cell membranes describes the phenomenon of a reversible increase in membrane conductance once a critical potential of about 1 to 2 V across the cell membrane is reached in response to an externally applied electric field pulse (ns to µs time course) [1-3]. Due to the breakdown the membrane becomes permeable to ions and, at higher external field strengths, even to macromolecules (proteins and DNA). The breakdown probably occurs in the lipid (lipoprotein) domain of the membrane. This assumption is supported by electrical breakdown studies on artificial lipid bilayer membranes and by the pressure dependence of the breakdown voltage. In terms of the electro-mechanical model introduced by Zimmermann et al. [2] to explain the mechanisms of electrical breakdown the magnitude of the breakdown voltage is determined by the elastic and dielectric properties of the membrane.

The breakdown of the membranes of cells suspended in solution is detected by measuring the size distribution of the cells as a function of increasing external electric field strength within the orifice of a hydrodynamically focussing particle analyzer [1-3]. Above a certain critical external field strength, an underestimation of the size of the cells occurs. Due to the breakdown of the cell membrane, which has normally a high resistance, and the subsequent increase in membrane conductance, the current lines pass partly through the cell interior [1]. The cell interior is much more conductive than the original membrane and causes a reduction in the cell induced signal. The degree of underestimation depends on the internal conductivity and the field-induced decrease in membrane conductance of the cell in relation to the external conductivity [1].

With a new multiparameter particle analyzer system breakdown experiments were performed on cloned BT 3Ce neurogenic rat tumor cells. The distribution of the breakdown voltage of the membranes of a tumor cell population shows two distinct peak values of about 0.85 V and 1.1 V, which are correlated with different relative volumes after breakdown. The results can be interpreted in terms of different cell cycle periods.

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2. Zimmermann, U., Pilwat, G. and Riemann, F. (1974) Biophys. J. 14, 881-899
3. Zimmermann, U., Pilwat, G., Beckers, F. and Riemann, F. (1976) Bioelectrochem. Bioenerg. 3, 58-83