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Electropulsation studies with 3D microdosimetric realistic models of cells and endoplasmic reticulum

Annalisa De Angelis A.[1], Laura Caramazza[2], Caterina Merla[3], Franck Andre[4], Lluis Mir[4], Francesca Apollonio[2] and Micaela Liberti[2]

[1] *Center for Life Nano Science@Sapienza, Istituto Italiano di Tecnologia, Rome, Italy; e-mail:annalisa.deangelis@iit.it*
[2] *ICEmB at DIET, University of Rome "La Sapienza", Rome, Italy; e-mail:micaela.liberti@uniroma1.it*
[3] *ENEA, SSPT - Division of Health Protection Technologies, Rome, Italy; e-mail:caterina.merla@enea.it*
[4] *CNRS, Univ. Paris-Sud, Université Paris-Saclay, Gustave Roussy, Villejuif, France; e-mail:lluis.mir@cnrs.fr*

In the last years, the study of the interaction between pulsed electric field (PEFs) and cells with organelles like the endoplasmic reticulum (ER) have gained increasing interest. In the study of the biophysical mechanisms at the basis of the EM field interaction to mediate biomedical applications, microdosimetric analysis aims to estimate the field strength at the microscopic scale to establish a quantitative relation between the applied field and the observed effect on cellular and sub-cellular structures, such as cell plasma membranes and organelles [1].
Here, a 3D realistic model of 12 cells with ER and nucleus is derived from initial images obtained from decorated cells observed with confocal microscopy, as previously described in [2] and [3] some significant electrical quantities representative of electroporation of both plasma and ER membranes are discussed.
A numerical model was realized in COMSOL 5.3, based on the dielectric properties of the cell as reported in [4]. The microdosimetric analysis of the cells group was quantified in terms of electric field and transmembrane potentials induced by an externally applied intense pulse. The electroporated local membrane sites and pore densities were also considered through the asymptotic model proposed by DeBruin and Krassowska [5]. As example of kinds of results we can report that a 10-ns pulsed electric field is able to porate both the ER and plasma membrane with field intensity slightly different, while 100-μs duration of sufficient intensity are able to porate not only the plasma membrane but also the reticulum one in spite of one can think based on the reduced spectral content of this second pulse. The non-uniformity in E field distributions was due to the difference in shape, size and position of the single cells with respect to the E field direction. Moreover, some portions of the cell and ER membranes showed a more important electroporation than others, coherently with the TMP estimation, due to their extremely irregular and folded structure.
These results highlight the importance to consider the realistic shape of the cell and its internal organelles in the microdosimetric analysis, in order to solidly validate the experimental results with reliable microdosimetric analysis.

References

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