3D microdosimetry of realistic models of cells and endoplasmic reticulum: spectral response at cellular and subcellular level

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While going down toward microscopic structures, the evaluation of the spatially-averaged electromagnetic (EM) exposure of tissues and organs is not sufficient since permittivity and conductivity heterogeneity of biological structures has to be taken into account [1]. Therefore, microdosimetric techniques and microscale models are needed for calculating the local distribution of the field on sub-cellular structures, such as cell membranes and organelles, to quantify the local electric field (**E** field) and identify molecular targets and cellular pathways [1]. In summary, **E** field at cell level is a complex function of frequency, shape, dielectric properties, and exposure conditions. Use of cell and sub-cellular models with realistic shapes in estimating such a microscopic **E** field is crucial for computational microdosimetry, e.g. applied to 2D neurons [1], 3D erythrocyte [2], 3D keratinocytes [3], 3D endoplasmic reticulum (ER) [4]. Also the modelling of cellular compartments electrical behavior, and in particular dispersive electromagnetic models of cell, are necessary for frequencies higher than hundreds of MHz [1], [3].

Here, a 3D realistic model of cells with ER and nucleus is derived from confocal microscopy images of decorated human mesenchymal stem cells, as previously described in [4], and some significant electrical quantities representative of plasma, ER and nuclear membranes are discussed. A numerical model was realized in COMSOL 5.3, based on the dielectric properties of the cell as reported in [1] and [4]. The microdosimetric analysis of the cells was quantified in terms of average **E** field in all plasmas and average transmembrane potential (TMP) induced by 1 V/m extracellular electric field in the 1 kHz – 100 GHz range (Fig.1a, b). A surface view of TMP on ER at 1 GHz is given in Fig.1-c.

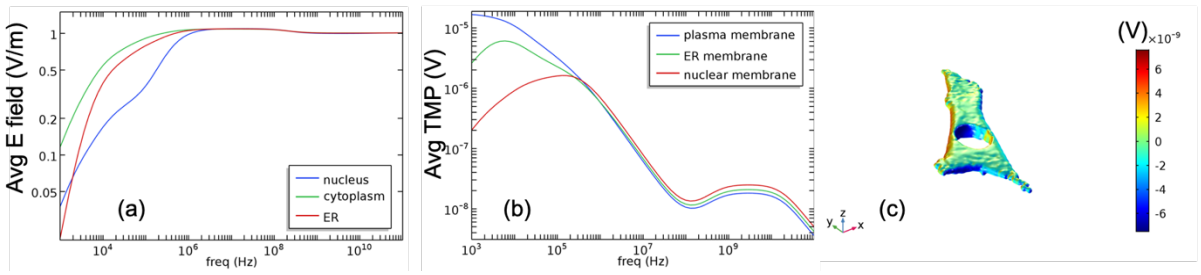

Fig 1: (a) Avg **E** field induced in all plasma, (b) Avg TMP induced in all membranes, (c) surface TMP on ER at 1 GHz.

It is worth to observe that high frequency spectral content can penetrate not only the plasma membrane reaching the organelle, but also the ER and nucleus membranes. This confirms the importance of the realistic shape of the cell and its internal organelles in the microdosimetric analysis, in order to accurately validate the experimental results with reliable microdosimetric analysis.

References

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