Advances in Magnetic Resonance Electrical Impedance Mammography

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Magnetic Resonance Electrical Impedance Mammography (MREIM) is a new imaging technique under development by Wollin Ventures, Inc. in conjunction with the H. Lee Moffitt Cancer Center & Research Institute. MREIM addresses the problem of low specificity of magnetic resonance mammography and high false-positive rates, which lead to unnecessary biopsies. Because cancerous tissue has a higher electrical conductivity than benign tissue, it may serve as a biomarker for differentiation between malignant and benign lesions. The MREIM principle is based on measuring both magnetic resonance and electric properties of the breast by adding a quasi-steady-state electric field to the standard magnetic resonance breast image acquisition. This applied electric field produces a current density that creates an additional magnetic field that in turn alters the native magnetic resonance signal in areas of higher electrical conductivity, corresponding to cancerous tissue.

This work comprises MREIM theory, computer simulations, and experimental developments. First, a general overview and background review of tissue modeling and electrical-impedance imaging techniques are presented. The experimental part of this work provides a description of the MREIM apparatus and the imaging results of a custom-made breast phantom. This phantom was designed and developed to mimic the magnetic resonance and electrical properties of the breast. The theoretical part of this work provides an extension to the initial MREIM theoretical developments to further un-

derstand the MREIM effects. MREIM computer simulations were developed for both idealized and realistic tumor models. A method of numerical calculation of electric potential and induced magnetic field distribution in objects with irregular boundaries and anisotropic conductivity was developed based on the Finite Difference Method. Experimental findings were replicated with simulations. MREIM effects were analyzed with contrast diagrams to show the theoretical perceptibility as a function of the acquisition parameters. An important goal was to reduce the applied current.

A new protocol for an MREIM sequence is suggested. This protocol defines parameters for the applied current synchronized to a specific magnetic resonance imaging sequence. A simulation utilizing this protocol showed that the MREIM effect is detectable for a 3-mm-diameter tumor with a current density of 0.5 A/m^2, which is within acceptable limits.