Very low current detection in MRI: Some limitations

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Target audience

People interested in detection of very low electrical currents using MRI.

Purpose

The term neuronal current MRI (ncMRI) is related with experiments or calculations performed to evaluate the MRI as a tool for direct detection of the neuronal activities [1]. Several groups have been detected variations of MR signal (magnitude and phase) *in vitro* and *in vivo* experiments due to the existence of very low electric currents, but the results are contradictory yet [2,3]. In the *in vitro* experiments a current phantom is used based on different effects: Ampère's Law (magnetic effect) and Lorentz Force (mechanical effect). In this study we model the magnitude and phase effect of one metallic wire with/without current, perpendicular to B_0, inside an infinite medium during a single EPI sequence. One experiment was made to evaluate the influence of the mechanical effect in a magnetic field sensitive experiment with low current phantom. We carry out an experimental comparison of the MR signal obtained in two solutions with the same magnetic permeability but different viscosities.

Methods

Theoretical simulation of the magnetic field effect on the magnitude and phase of MRI signal was made to evaluate the wire position effect inside a square pixel (1x1 mm^2). In the simulation was considered the susceptibility effect and the possible movement of the cooper wire. Two current phantoms formed by insulated thin cooper wire (100 µm diameter, like in the simulation) and filled with solutions of equal magnetic permeability nevertheless different viscosities (liquid and gelatin) had been tested. By the wire was passed a squared electric current wave pulse in three intensities (20, 40 and 60 µA) in a 250 mHz frequency (2 s off and 2 s on cycle). The imaging experiment was performed in a 3 T scanner (Achieva, Philips) using a triggered conventional EPI with the following parameters: TR/TE =100/33 ms, FOV = 224x224 mm^2, acquisition matrix with 224x224 pixels in a unique coronal slice with 4mm of thickness. We acquired 400 dynamics scans in each run; therefore the time spent with each acquisition was 40 seconds. We utilized a t-test to differentiate the pixels that had a signal difference between both states (on/off) in each solution, called as "activated" pixels.

Results

The figure 1 shows the phase and magnitude variations in the wire pixel in two theoretical conditions: a) Turn off/Turn on (60 µA) the current disregarding the wire´s movement for different wire position along the voxel, b) Turn off the current considering a possible mechanical effect and the wire in a corner of the voxel. For 60 µA in the liquid phantom the signal loss detected in the magnitude and phase images were 18 % and 11°, respectively. In the gelatin phantom these values were 2 % and 8°, respectively. The figure 2 illustrates the comparison of the number of "activated" pixels per current intensity in each solution for the phase and magnitude data.

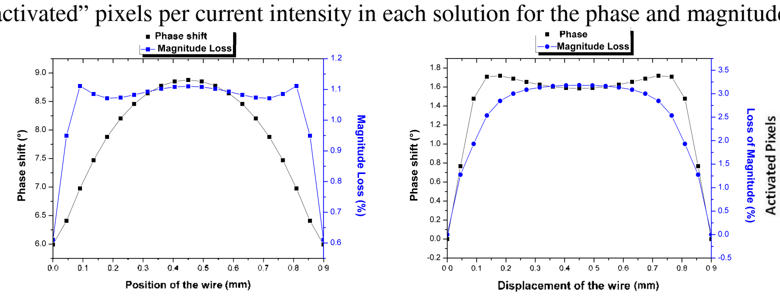

Figure 1: Simulation results: a) No wire´s movement, b) Turn off the wire´s current.

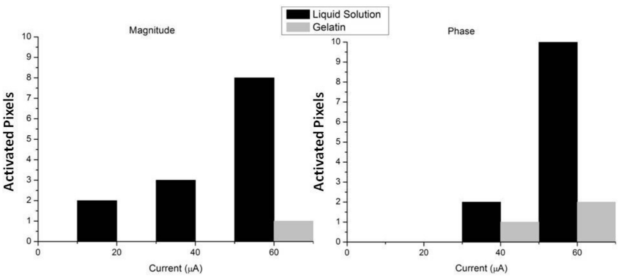

Figure 2: Experimental results for both phantom compositions.

Discussion

The figure 1-a) evidences the strong effect of the wire position inside the voxel, the most variation is in the pixel phase. By other hand the wire's movement induces a susceptibility effect that influences the pixel magnitude, mainly. The experimental results dissimilarity between both phantoms can not be totally explained by different wire positions inside the voxel in the experiment. Furthermore, from theoretical simulation, the magnetic effect is not enough to justify the magnitude variation obtained in the liquid and low current case. We believe that a small wire's displacement in the liquid solution conjugated with susceptibilities artifact (wire-solution interface) are influencing the measured variations.

Conclusion

The wire position inside the voxel and the mechanical properties of the medium have a strong influence in the magnitude and phase of the MRI signal in an *in vitro* ncMRI experiment. We conclude that mechanical effect could be dominant in very low current and low viscosity phantoms. We believed that the uncertain of the position of the conductor elements (neurons) in a real brain unfeasible a reliable *in vivo* ncMRI experiment in the current technology conditions (spatial resolution and signal-to-noise).

References

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