Electrode Misalignment Correction Algorithms In Magnetic Resonance Electrical Impedance Tomography

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Purpose

In Magnetic Resonance Electrical Impedance Tomography (MREIT) electrical currents are injected into an object and the resulting magnetic flux density distribution measured using MRI. These MRI measurements are then used to reconstruct the conductivity distribution within the object. Many of the reported MREIT reconstruction algorithms utilize numerical calculation of the magnetic flux density for a given conductivity distribution using the boundary conditions applied to the real object. This corresponds to matching the position of the electrodes in the numerical computation to that of the actual position of the electrodes on the object. Near an injecting electrode, there exists a large variation in the magnetic flux density. As a result, any misalignment in the position of an electrode can result in significant errors when calculating the difference between the computed magnetic flux density distribution and the MRI-measured magnetic flux density distribution. Such errors may generate artifacts in the final reconstructed conductivity distribution. In this study, we investigate various correction algorithms to reduce these artifacts.

Method

For the test phantom, a hollow acrylic disk with an inner diameter of 7cm and thickness of 1cm was filled with 2% agarose, 0.1% NaCl, and 4mM $CuSO_4$. Within this disk, a smaller circular region of 12mm diameter was filled with 2% agarose, 1% NaCl, and 4mM $CuSO_4$ (Figure 1). The conductivities of the different regions were measured using the 4-electrode method and found to yield a contrast ratio of 1 to 7.4. The plane of the disk was placed perpendicular to the main static MRI field. Four copper electrodes each 6mm wide were placed equidistant along the inner acrylic wall and used to inject currents into the interior region.

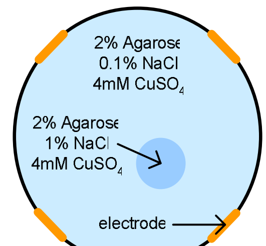

Figure 1. Schematic of the phantom

A finite alternating current pulse waveform with an amplitude of 900uA was injected into the phantom and the resulting magnetic flux density distribution measured using a modified spin-echo pulse sequence (Figure 2) [*Mikac et al, MRI 19: 845-856 (2001)*]. The scan parameters were TR=500ms, TE=60ms, NEX=4, Matrix=64X64, FOV=10cm, and single slice thickness = 5mm. Data was collected for two different current injection schemes (in pairs of electrodes directly opposite of each other) and used simultaneously in conductivity reconstruction. To reconstruct the conductivity distribution using the MRI measurements, the Sensitivity Matrix Method was utilized [*Birgul et al, Phys Med Bio 48: 3485-3504 (2003)*] in which the relationship between conductivity and magnetic flux density is linearized around an initial conductivity (i.e. uniform distribution) and formulated as a matrix equation. This equation is then solved for the true conductivity distribution using Tikhonov regularization. The resulting conductivity can then be substituted back into the linearized equation as the new, updated initial condition, and the process iterated to improve the reconstruction.

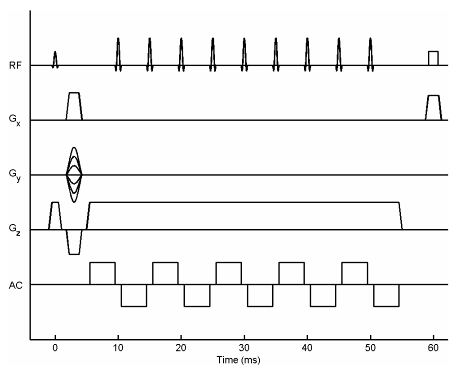

Figure 2. Pulse sequence used in MREIT

Three different electrode misalignment correction algorithms can be implemented during reconstruction. For the first algorithm (MASK), magnetic flux density measurements within 1cm of the electrodes were discarded and not used during reconstruction. For the second algorithm (SHIFT), the position of each electrode assigned during numerical computation was perturbed to find the best location. The difference between the MRI-measured magnetic flux density and the calculated magnetic flux density given the initial condition was minimized as a function of electrode position. For the third algorithm (REG), conductivity perturbations within 1cm of the electrodes were suppressed by a factor of 2 when compared to the rest of the phantom through increased weighting in the Tikhonov regularization.

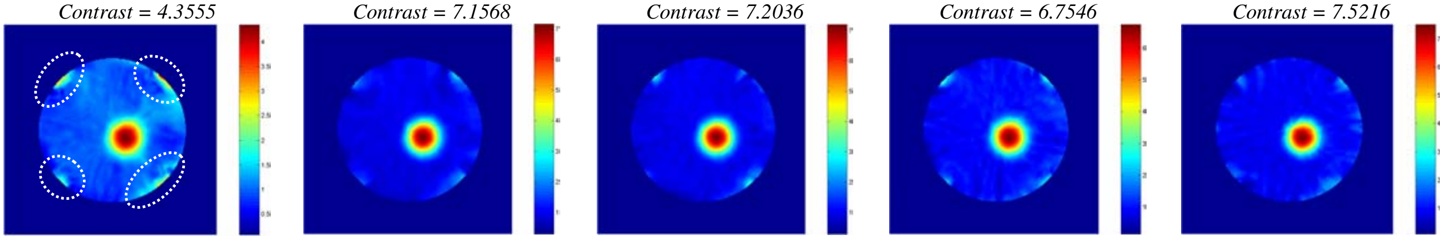

Figure 3a *Figure 3b* *Figure 3c* *Figure 3d* *Figure 3e*

Figure 3. (a) Reconstructed conductivity distribution using no correction; (b) MASK; (c) SHIFT; (d) REG; (e) all 3 algorithms

Results

Data was collected using a 4T MRI system. Conductivity distributions were reconstructed for various combinations of electrode correction algorithms using 5 iterations of the Sensitivity Matrix Method (Figures 3a-e). For each reconstructed image, the contrast between the high and low conductivity regions was calculated by finding the maximum conductivity value and dividing it by the mean conductivity of the background. The background conductivity was calculated by finding the average conductivity of the phantom excluding a 2cm diameter disk centered on the high conductivity region.

Discussion

The results of this study indicate that electrode misalignment affects the reconstructed conductivity distribution throughout the phantom. Regions next to the electrodes contain artifacts as circled in Figure 3a, while objects in the interior region suffer from diminished contrast. Each of the proposed correction algorithms improves the reconstruction, with the best result occurring when all three methods are applied.

Acknowledgement

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