Feasibility of Submillimeter Resolution MREIT Conductivity Imaging: Preliminary Phantom Study

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Purpose

The purpose of this study is to find the feasibility of MREIT providing conductivity contrast information at a spatial resolution with a submillimeter pixel size.

Materials and Methods

We used an octagon-shaped acrylic phantom shown in figure 1. Its four long edges were 15 mm and the other four short edges were 10 mm. We installed four recessed electrodes to inject currents. We placed two hollow cylindrical anomalies of thin insulating films (cellulose acetate, 0.3 mm thickness) with 5 mm diameter. On the side of one hollow cylinder, we made four equally-spaced holes along the central plane of the phantom where current-injection electrodes were located. We filled the background of the phantom including inside and outside of the two hollow cylinders with a saline of 0.12 S/m conductivity (0.3 g/l NaCl and 1 g/l $CuSO_4$).

For imaging experiments, we placed the phantom inside the bore of a 4.7 Tesla MRI scanner (BioSpec 47/40, Bruker). Using a custom-designed MREIT current source, we injected the first current I_1 between one pair of electrodes. The injection current amplitude was 3 mA with the total pulse width of 28 ms. The multi-echo ICNE pulse sequence was used with TR/TE = 800/20 ms, FOV = 55×55 mm^2, slice thickness = 2 mm, NEX = 8, matrix size = 128×128, number of slices = 7, and total imaging time = 40 min. After acquiring the first magnetic flux density (B_z) data set for I_1, the second injection current I_2 with the same amplitude and pulse width was injected through the other pair of electrodes to obtain the second data set. We used the single-step harmonic B_z algorithm implemented in CoReHA (conductivity reconstructor using harmonic algorithms) for multi-slice conductivity image reconstructions.

Results and Discussion

Figure 1 shows current injection for imaging experiment (a), MR magnitude (b), magnetic flux density (c), and reconstructed conductivity (d) images, respectively, of the phantom with two cylindrical anomalies. The pixel size of the images was 400 μm. The anomaly on the left (with four holes) shows a different conductivity compared with the one on the right (without holes). Such a contrast was not seen in the magnitude image in figure 1(b). Note that the anomaly on the right appears to be an insulator since we are producing a conductivity image at a low frequency in MREIT.

Figure 2(a) and (b) show reconstructed conductivity images at spatial resolutions of 1.4 and 1 mm, respectively. The conductivity images in (c) and (d) were reconstructed from the second octagonal phantom with two anomalies at spatial resolutions of 400 and 200 μm, respectively. All the conductivity images except the one with 200 μm pixel size showed clear contrast between two different anomalies. The conductivity image with 200 μm size was too noisy compared with other cases primarily due to a poor SNR in measured data. Figure 3 shows comparison of reconstructed conductivity images at two different pixel size. The conductivity contrast between two different anomalies in 400 μm pixel size shows similar pattern that of 1.4 mm pixel size.

Conclusion

The results demonstrate that the existing MREIT technique can produce conductivity images with a pixel size of as small as 400 μm. Using the multi-echo pulse sequence and high-performance small volume RF coil, we could do this with imaging currents of 3 mA. We plan to apply the developed experimental method to *in vivo* head imaging of small animals to investigate the feasibility of functional MREIT as a new neuro-imaging method.
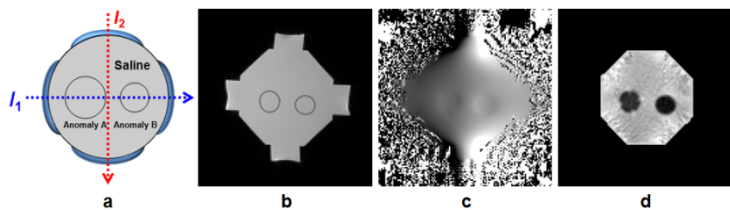

Fig. 1. (a) Current injection method, (b) MR magnitude, (c) magnetic flux density, and (d) reconstructed conductivity images of the phantom with a 400 μm pixel size.
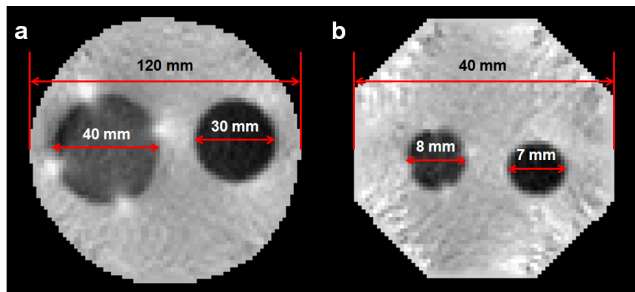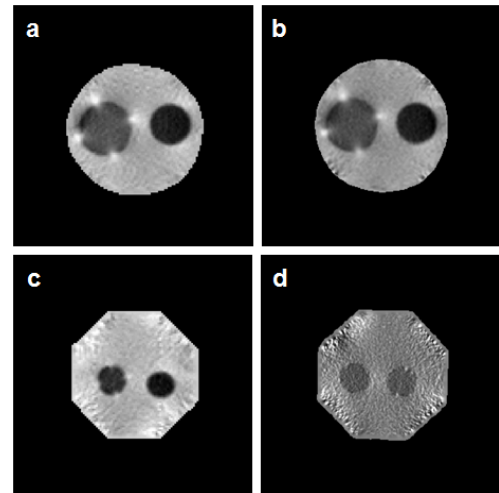

Fig 2. Reconstructed conductivity images of two different anomalies at different spatial resolutions: (a) 1.4 mm, (b) 1.0 mm, (c) 400 μm and (d) 200 μm.

Fig. 3. Comparison of reconstructed conductivity images at two different spatial resolutions. (a) 1.4 mm pixel size, (b) 400 μm pixel size.

References

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