Breast MR Electrical Impedance Tomography toward Breast Cancer Imaging

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Introduction

Breast cancer is one of the most life-threatening tumors. Early detection and diagnosis are known to be the keys to survive from the cancer. Currently X-ray mammography is the only standard screening modality. However due to inherent limitations of mammography such as X-ray dose, limited soft tissue contrast, and no tomographic view, breast MRI is actively being investigated. However despite of its high sensitivity, effectiveness for dense breast, and stereotactic information, its low specificity (~50%) and inability to image calcifications limit its wide-spread use. In this work, we introduce a new imaging modality for breast imaging using MR electrical impedance tomography (MREIT) [1]. Since conductivity is known to be high for cancerous tissues, breast MREIT provides a potential of improving specificity via tomographic conductivity images. We have tested the basic capability of breast MREIT using a breast phantom containing several objects differing in conductivity. Our preliminary results show the objects, which could not be differentiated in MR images, are clearly differentiated in conductivity images.

Methods

In breast MREIT, currents are injected into the breast using the surface electrodes, $\mathbf{E}_i$ as shown in Fig. 1 (a). Four current injections according to the injection pathways drawn in Fig. 1 (a) are made. Then using MRI (3.0T Medinus Inc., Korea), we have measured the induced magnetic flux density in the main magnet direction ($\mathbf{B}_z$) from a breast phantom as shown in Fig. 1 (b). In the breast phantom, that was filled with NaCl solution (0.35S/m), three objects (polyacrylamide anomalies denoted as PAA) differing in conductivity (0.52S/m, 0.45S/m, and 0.22S/m) were positioned as shown in Fig. 1 (a). Breast MREIT imaging parameters include TR=300ms, TE=14ms, FOV=240x240mm^2, matrix size 128x128, NEX=4, slice thickness=3mm, 8 slices, and injection current amount/duration: 24mA/9msec. Conductivity images were reconstructed using the harmonic $\mathbf{B}_z$ algorithm [2] with our special regularization technique [3].

Results

A typical MR magnitude image out of eight is shown in Fig. 1 (c) showing three PAA objects. As shown, three objects are not clearly differentiable in terms of MR intensity values. Fig. 1 (d) shows a conductivity image corresponding to the slice in Fig. 1 (c). The reconstructed values of conductivity for the PAAs were 0.43S/m, 0.33S/m, and 0.21S/m from left to right. Except the less-visible second PAA which has the reconstructed conductivity value similar to the background solution, other PAAs are clearly differentiated in terms of their conductivity values. Note the artifacts (white spots) due to the current injection electrodes which could be reduced by the use of recessed electrodes [1,2].

Conclusions

Although the presented results are preliminary with phantoms studies only, the results suggest breast MREIT could be a potential imaging technique to improve specificity of conventional breast MRI for cancerous breast tissues. Remaining challenges in breast MREIT include how to reduce the amount of injection current and how to improve SNR. Considering innovations in hardware and software such as special breast coils in the future, our results indicate that breast MREIT could be a potential imaging technique for early detection of breast cancers.

References

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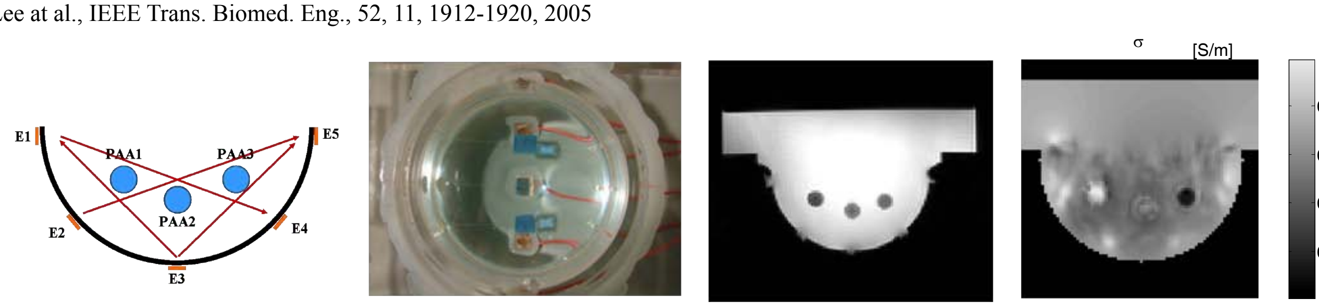

(a) (b) (c) (d)

Fig. 1. (a) Illustration for current injection pathways and imaging objects inside the breast phantom, (b) picture of the breast phantom, (c) MR magnitude image, and (d) reconstructed conductivity image. The anomalies which could not be differentiated in the MR magnitude image in (c) are clearly differentiated in the conductivity image in (d)