Correlation between the electric conductivity measured by MREPT and apparent diffusion coefficient in invasive breast cancer

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Background and Purpose

Magnetic resonance electric properties tomography (MREPT), a method of imaging conductivity using a standard MRI system, has shown its clinical feasibility and ability to differentiate benign breast tissue from malignant breast tissue, as malignant breast tissue has higher conductivity values than does benign breast tissue [1-2]. Diffusion-weighted MRI is a non-contrast MR sequence based on the Brownian motion of water molecules. Tumor cellularity is inversely correlated with apparent diffusion coefficient (ADC), and breast tumors with higher cellularity show lower ADC values than those of benign breast lesions [3]. It is regarded that conductivity and ADC are related with the same boundaries (e.g. cell membranes), since conductivity depicts the movement of ions and ADC depicts the movement of water molecules across the cell membrane [4]. There have been limited experimental and no in-vivo studies regarding the relationship between conductivity and ADC in invasive breast cancer at 3T MRI. Therefore, the purpose of this study was to investigate the relationship between conductivity and ADC in invasive breast cancer in invasive breast cancer.

Materials and Methods

The electric conductivity values of 33 invasive breast cancers larger than 1 cm on T2-weighted fast spin echo (FSE) were evaluated using the EPT reconstruction algorithm [1] and multi-receive coil combined technique [2]. Breast MRI examinations were performed on a 3.0-T system (MR750, GE Healthcare, Waukesha, WI, USA) with an 8-channel breast receiver coil. T2-weighted FSE axial images (TR/TE, 9100/100msec; flip angle, 110°; field of view (FOV), 320mm; matrix, 416x256 pixels; slice thickness, 3mm; with no slice gap) were used for the reconstruction of conductivity. ADC values of each tumor were measured with a computer aided detection system (CADstream software, version 5.2.8.591, Merge Healthcare, Milwaukee, WI, USA) using the following formula: ADC= [1/(b2-b1)] x ln [S1/S2], where S1 is the signal intensity obtained at b=0s/mm^2 and S2 is the signal intensity obtained at b=600s/mm^2. Correlation between conductivity and ADC was evaluated using Spearman's correlation test.

Results

Mean conductivity value was 0.53±0.29S/m, ranging from 0.19 to 1.65S/m. Mean ADC value was 1.17±0.25x10^{-3}mm^2/sec, ranging from 0.82 to 2.18mm^2/sec. Conductivity showed an inverse correlation with ADC (Fig. 1. correlation coefficient = -0.374, P-value=0.032). Two representative cases demonstrating the inverse correlation between ADC and conductivity are shown in Figs. 2 and 3. There were two tumors (Fig. 3 and another case) with central necrosis in this study. When the two tumors with central necrosis were excluded from the analysis, conductivity showed higher correlation with ADC (rho=-0.491, P-value=0.005).

Discussion

In this study, there was a significant inverse correlation between conductivity and ADC in invasive breast cancer. This means that there is significant positive correlation between conductivity and cellularity, because cellularity is inversely correlated with ADC. Increased cellularity may increase conductivity due to the overall increased amount of cells (e.g. ions). Our results also show that necrosis may have an effect on conductivity value. When necrosis occurs, cellularity decreases. Decreased cellularity caused by necrosis may decrease conductivity due to overall decreased amount of ions. In the opposite direction, there is a possibility that necrosis may increase conductivity because cell membranes (which are barriers for ionic movement) are disrupted by necrosis. Further studies are needed with larger sample size to determine the relationship among conductivity, cellularity, and necrosis.

Conclusion

There is an inverse correlation between conductivity and ADC in invasive breast cancer. Necrosis may have an effect to increase conductivity since cell membranes that are barriers for ionic movement are disrupted by necrosis.

References

[1] Katscher U et al. Recent progress and future challenges in MR electric properties tomography. Computational and mathematical methods in medicine 2013;2013(Article ID 546562). [2] Shin JW et al. Initial study on in-vivo conductivity mapping of breast cancer using MRI. Journal of Magnetic Resonance Imaging 2014; accepted for publication. [3] Guo Y et al. Differentiation of clinically benign and malignant breast lesions using diffusion-weighted imaging. Journal of Magnetic Resonance Imaging 2002;16(2):172-178. [4] Hancu I et al. On conductivity, permittivity, apparent diffusion coefficient, and their usefulness as cancer markers at MRI frequencies. Magnetic Resonance in Medicine 2014; e-published 19 Jun 2014.

Figure 1 (left). An inverse correlation between conductivity and ADC (correlation coefficient= -0.374, P-value=0.032).

Figure 2 (right upper). (a) T2-weighted FSE and (b) T1-weighted fat-suppressed contrast-enhanced image demonstrate 1.1cm sized invasive ductal carcinoma. ADC map (c) revealed ADC value of 0.82x10^{-3}mm^2/s, the lowest ADC value among the study samples. Conductivity map (d) revealed conductivity of 1.65S/m, the highest conductivity value among the study samples.

Figure 3 (right lower). Figure 3. (a) T2-weighted FSE and (b) T1-weighted fat-suppressed contrast-enhanced image demonstrate 2.2cm sized rim-enhancing invasive ductal carcinoma with central necrosis. ADC map (c) revealed ADC value of 2.19x10^{-3}mm^2/s, the highest ADC value among the study samples. Conductivity map (d) revealed conductivity of 0.50S/m, which was not the lowest conductivity.