Towards the investigation of breast tumor malignancy via electric conductivity measurement

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Introduction: According to *ex vivo* studies, breast tumors exhibit a significantly altered electric conductivity [1,2]. This feature opens the chance to increase the specificity of breast tumor characterization with MRI. The electric conductivity can be measured *in vivo* using "Electric Properties Tomography" (EPT) [3,4]. EPT has shown its potential in phantom, volunteer, and initial clinical studies [5,6]. Due to the complex frayed structure of fat and ductile tissue in the breast, an EPT reconstruction algorithm dedicated for breast tissue has been developed [7], which is applied in this study to eight breast cancer patients. The study tries to contribute to the discussion if breast tumor conductivity can be measured reliably with EPT, aiming for future tumor malignancy staging.

Theory: Given the transceive phase φ of a turbo spin echo (TSE) image [3,4], EPT estimates tissue conductivity via $\sigma = (\Delta\varphi)/(2\mu_0\omega)$ with Δ the Laplacian operator, μ_0 the magnetic permeability, and ω the Larmor frequency. To reduce boundary artefacts, this study determines σ not by the second derivative of φ as in [3,4], but by locally fitting a 3D-parabola to φ as suggested for breast imaging in [7]. The local parabola fitting is limited to voxels with $R(\mathbf{r}) = |A(\mathbf{r})/A(\mathbf{r}_{target}) - 1| < R_{thresh} = 50\%$ with $A(\mathbf{r})$ the amplitude of the TSE image, which has been acquired to determine φ. Subsequently, a median filter is applied, which is also locally restricted to voxels with $R_{thresh} = 50\%$.

Breast tumor study: Eight patients, each with a breast-containing lesion, were imaged on a 3T system (Philips Achieva TX, Best, Netherlands) with a 16 channel breast coil using a 3D TSE sequence (TR/TE=2000/210 ms, voxel size=0.7×07×0.8 mm³). Four lesions were classified as malignant and four benign. The tumors were located using pre/post-contrast subtraction images.

Results: For one of the benign cases, Figure 1 compares the TSE image (magnitude), pre/post-contrast subtraction image, and the reconstructed conductivity, showing clearly a tumor in the center of the left breast. An overview of the 8 cases (FoV reduced to ~6×6 cm²) is given in Fig. 2 (upper row: benign cases, lower row: malignant cases, same color scale applied for all images). The conductivity of all benign lesions are below ~2-3 S/m. One malignant lesion has a conductivity below ~2 S/m, the other three malignant tumors show conductivities up to ~4-6 S/m.

Discussion / Conclusion: In all eight investigated cases, conductivity reconstructed with dedicated breast EPT shows significant maxima in suspicious areas from pre/post contrast subtraction images. Thus, EPT could be a tool to investigate breast tumor malignancy in future systematic studies. The hitherto obtained initial results are not completely incompatible with the hypothesis that conductivity increases with malignancy. The presented study is regarded as an initial step towards a systematic study investigating a possible correlation between tumor malignancy and conductivity.

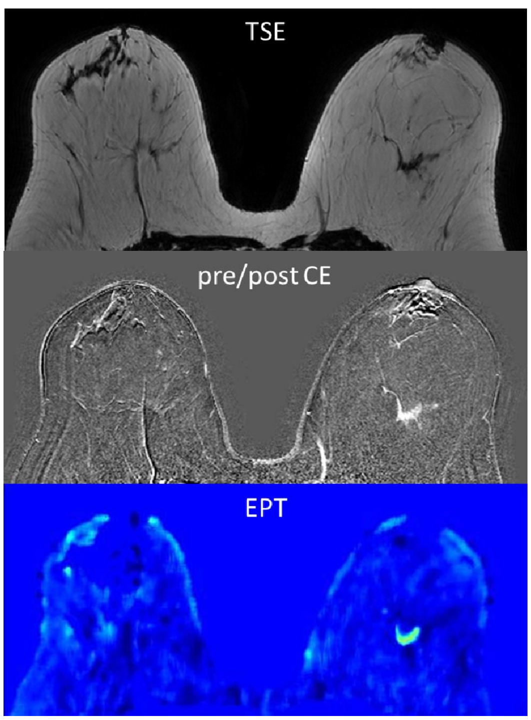

Fig. 1: Example case of breast cancer. Above: TSE image, middle: subtraction image of pre/post contrast enhanced image, below: reconstructed conductivity.

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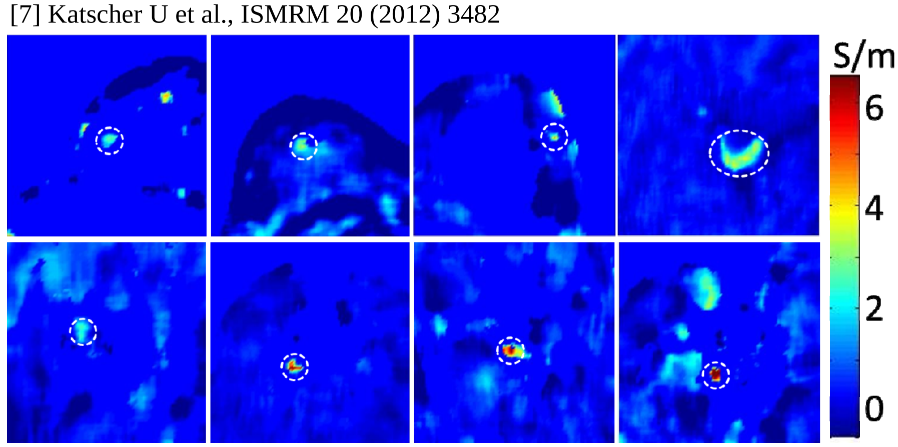

Fig. 2: Breast cancer examples. Upper row: benign cases, lower row: malignant cases. The FoVs are reduced to roughly 6×6 cm² around the tumors, indicated by white circles. The same color scale is applied for all images.