Estimation of breast tumor conductivity using parabolic phase fitting

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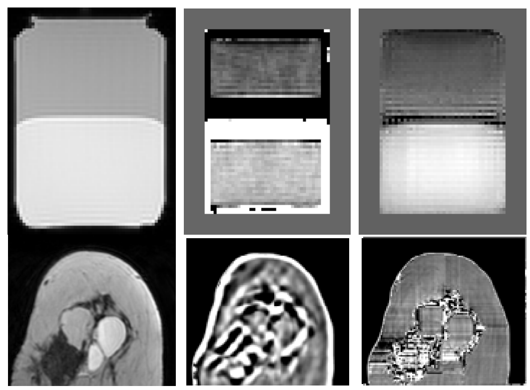
Introduction: According to *ex vivo* studies, breast tumors exhibit a significantly altered electric conductivity [1,2]. This feature opens the chance to increase the specificity of breast tumor characterization with MRI. The electric conductivity can be measured *in vivo* using "Electric Properties Tomography" (EPT) [3-5]. EPT has shown its potential in phantom, volunteer, and initial clinical studies [6,7]. However, the complex frayed structure of fat and ductile tissue in the breast hampers the straight-forward application of EPT, based on the second derivative of the RF transmit (TX) phase. In this study, a new EPT reconstruction algorithm, based on fitting local parabolic functions on the TX phase, is developed and applied to an example breast tumor.

Theory: Given the TX phase φ, typically derived by dividing in half the transceive phase of a turbo spin echo (TSE) image [4-7], EPT suggests to estimate tissue conductivity $\sigma = (\Delta\varphi)/(\mu\omega)$ with Δ the Laplacian operator, μ the magnetic permeability, and ω the Larmor frequency. Thus, σ can be determined by the second derivative of φ as usually applied [4-7], or alternatively by locally fitting a 3D-parabola to φ as tested in this study. The two methods are mathematically equivalent for the assumed locally constant conductivity. However, parabola fitting has the following two major advantages. <u>(1) Removing boundary artefacts:</u> the numerical calculation of the Laplacian from a voxel ensemble around the target voxel (the "kernel") typically requires at least one voxel on each side of the target voxel. Thus, if the target voxel is at the boundary of two tissue compartments, the Laplacian requires at least one voxel from the "wrong" compartment with a different conductivity, leading to oscillatory artefacts [4]. The parabola fitting can be performed with the target voxel at the edge of the kernel, thus avoiding the described boundary artefacts. The boundary is identified by the amplitude $A(\mathbf{r})$ of the TSE image, which has been acquired to determine φ, by limiting the kernel to voxels with $R(\mathbf{r}) = |A(\mathbf{r})/A(\mathbf{r}_{target}) - 1| < R_{thresh}$. <u>(2) Check local reconstruction quality:</u> The similarity of fitted parabola and measured phase is benchmarked via the correlation coefficient $c(\mathbf{r})$. A threshold c_{thresh} is set to reject voxels with too low correlation $c(\mathbf{r}) < c_{thresh}$. This criterion can also be used to identify boundaries between compartments of different conductivity.

Phantom study: Figure 1a (upper row) shows a TSE image (TR/TE=105/4.6 ms, voxel size=1.6×1.6×3.5 mm³) of a phantom with saline (lower part, σ = 0.75 S/m) and oil (upper part, σ = 0.05 S/m) from a 3T scanner (Philips Achieva, Best, Netherlands). With an isotropic kernel of 6 voxels around the target voxel, the conductivity reconstruction based on the Laplacian leads to significant artefacts (over/undershooting) along the fat/water boundary (Fig. 1b). In the reconstruction based on parabola fitting using R_{thresh} = 5% and c_{thresh} = 70%, boundary artefacts are significantly reduced (Fig. 1c).

Breast tumor study: The breast of a woman with cancer in the right upper outer quadrant was 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). The lower row of Figure 1 demonstrates the effect of the discussed EPT reconstruction algorithm (R_{thresh} = 20% , c_{thresh} = 70%) with a detail of the breast image, showing similar results as in the phantom study. The complete image is shown in Fig. 2. After the described EPT reconstruction, a median and a Gaussian filter were applied, which were also restricted to voxels with R_{thresh} = 20%.



(a) (b) (c)

Fig. 1: Different EPT reconstructions. Upper row: saline/oil phantom, lower row: breast (detail). (a) TSE image, (b) conductivity reconstructed with unrestricted kernel size, (c) conductivity reconstructed with kernel size restricted by TSE contrast of (a).

Discussion / Conclusion: Replacing the Laplacian-based EPT reconstruction by parabola-fitting improves the results for intricate conductivity distributions as found in breast imaging. A systematic breast study, based on the presented EPT refinement, is under way. It is expected that this approach shows advantages also for conductivity mapping of other body parts.

References:

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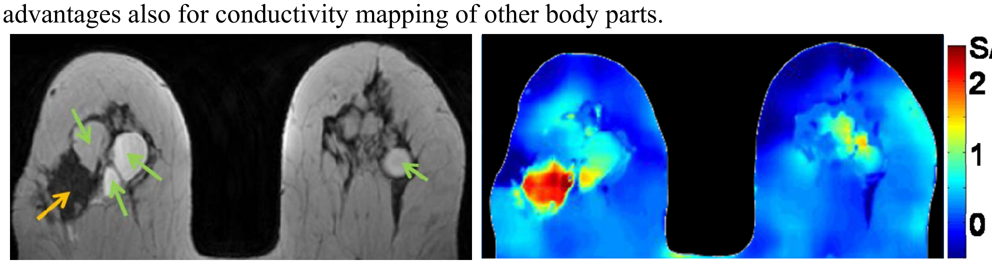

(a) (b)

Fig. 2: Breast cancer example. (a) TSE image, showing several cysts (green arrows) and tumor (orange arrow). (b) Conductivity of breast shown in (a). Low/medium/high conductivity is found for fat/cysts/tumor, respectively.