Investigating breast tumor malignancy with electric conductivity measurement

Ulrich Katscher[1], Hiroyuki Abe[2], Marko K Ivancevic[3], and Jochen Keupp[1]
[1]*Philips Research Europe, Hamburg, Germany,* [2]*Medical Center, University of Chicago, Chicago, Illinois, United States,* [3]*Philips Healthcare, Best, Netherlands*

Target audience: Radiologists / clinicians / physicists engaged in breast tumor imaging / classification

Purpose: 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]. With EPT, a trend towards a correlation between conductivity and malignancy has been indicated in initial breast tumor studies [5,6], however, without statistical significance. This study is testing a statistically significant correlation between conductivity and malignancy, based on 29 breast tumors. To this goal, the lesion volume derived from pre/post contrast subtraction images was used as *a priori* information to stabilize EPT reconstruction. According to the results obtained, EPT is able for tumor malignancy staging.

Theory / Methods: Given the transceive phase φ of a turbo spin echo (TSE) image, EPT estimates tissue conductivity via $\sigma = (\Delta\varphi)/(2\mu_0\omega)$ with Δ the Laplace operator, μ_0 the magnetic permeability (assumed to be constant), and ω the Larmor frequency [4]. Conductivity reconstruction was performed only inside lesion volumes, which have been semi-automatically segmented from pre/post-contrast subtraction images. To avoid artefacts along lesion boundaries, the numerical kernels of the Laplace operator and the subsequent median filter [5] were limited to the lesion volumes. – 23 patients (29 lesions, lesion diameter at least 5 mm) 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=0.7×0.7×0.8 mm³). Pathologically proven, 11 lesions were classified as benign, the other 18 as malignant (15 invasive ductal carcinomas, 3 ductal carcinomas in situ).

Results: For one of the malignant cases, Fig. 1 compares the TSE image, pre/post-contrast subtraction image, and the conductivity reconstructed inside the lesion. A box-whisker plot (median/upper+lower quartile/upper+lower extreme) comparing mean conductivities of the 11 benign and 18 malignant lesions is shown in Fig. 2. The mean conductivity averaged over malignant lesions is 1.86 ± 0.64 S/m, the mean conductivity averaged over benign lesions is 0.43 ± 0.73 S/m. The corresponding ROC is given in Fig. 2b, yielding an AUC of 93.4%.

Discussion / Conclusion: This study reveals a statistically significant difference between conductivity of benign and malignant breast lesions. This difference might arise from different sodium concentration in benign and malignant lesions [7], since sodium concentration was reported as potential major determinant of electric tissue conductivity [8]. The observed difference opens the chance to increase the specificity of breast tumor characterization with MRI. Further studies shall investigate a potential correlation between electric conductivity and tumor grade.

References

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Fig. 1

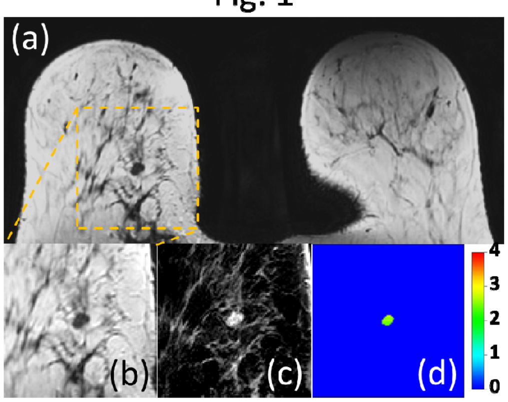

Fig. 2(a) Fig. 2(b)

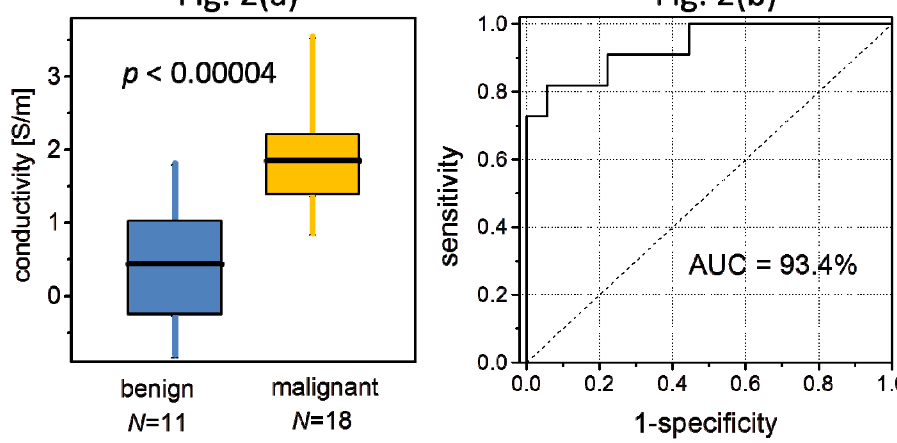

Figure legends

Figure 1: Example case of malignant breast lesion (satellite of invasive ductal carcinomas, grade 3). (a) TSE image of whole breast, (b) TSE image with lesion zoomed, (c) pre/post-contrast subtraction image of zoomed area, (d) reconstructed conductivity of tumor (color scale in S/m). Figure 2: Comparing mean conductivities of benign and malignant lesions via (a) box-whisker plot (two-sided t-test $p < 0.00004$) and (b) ROC, yielding an AUC of 93.4%.