Comparison of different diffusion parameters in DWI for differentiation of breast lesions at 3.0 Tesla – Effects of perfusion and diffusion compartments on ADC

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Introduction:

Conventional breast MRI may reach a high sensitivity (88-100%), but variable specificity (75-98%) [1]. Recently the specificity could be increased using diffusion weighted imaging (DWI) [1,2] on 1.5T systems. Previous studies used very different diffusion weighting schemes, maximum b-values ranging from 300 to 1000 s/mm², and the number of weightings from two to five [1,2]. Therefore an evaluation of different schemes was recently proposed [3].

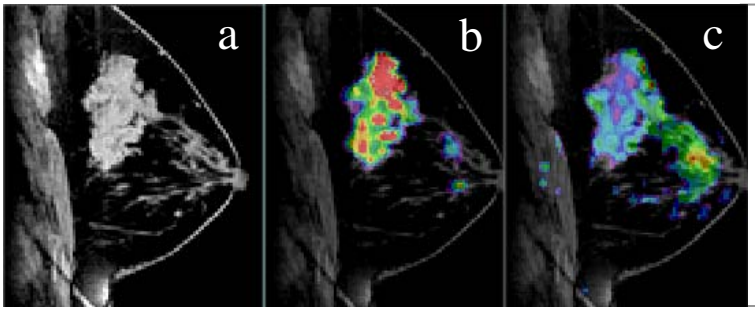

Fig. 1: A ductal carcinoma in situ (DCIS) on: (a) contrast-enhanced T1-weighted MRI, (b) color-coded DWI (b=850 s/mm²) and (c) ADC-map (ADC mean ±SD = 1.03 ±0.13 x10-3 mm²/s) illustrates low diffusivity in malignant lesions.

Methods and Materials:

Seventy-four patients were examined on a 3T system (Tim Trio®, Siemens, Erlangen, Germany) using a bilateral 4 channel breast coil. DWI was performed with a twice-refocused EPI diffusion sequence using inversion-recovery fat suppression: (TR/TE/TI, 13700/83/220 ms, axial FOV, 340x117 mm, matrix, 192x64 oversampled to 192x96, 40 slices , SI 3.5 mm, no gap, 2 averages). All measurement parameters except for b-values were kept constant: Ten b-values 0, 50, 100, 250, 400, 550, 700, 850, 1000, 1250 s/mm² in 3 directions. Total measurement time was 13:12 min.

Apparent diffusion coefficient (ADC)-maps were calculated from different combinations of the measured b-values by linear regression using Matlab (MathWorks, Natick, MA, USA). ROIs were drawn in cysts, benign, malignant, and healthy tissue on DWIs (b=1250 s/mm²) and subsequently copied automatically to all associated DWI and ADC maps. All benign and malignant lesions were histologically verified. The mean ADC and contrast-to-noise ratio (CNR) of DWIs were determined for different schemes in all ROIs. The coefficient of variation (CV) was determined as a measure of precision for the ADC determination. Statistical evaluation was performed by SPSS 15.0 (Chicago, Illinois, USA). ADC calibration measurements using dimethylsulfoxid and water were performed.

Results:

In one-hundred-thirty-nine ROIs the following mean ADC values were found when fitting intensities of all b-values (29 cysts/ 17 benign/ 24 malignant/ 69 healthy; 2.63±0.37, 1.47±0.21, 0.99±0.18, and 1.85±0.20 mm²/s). Significant ADC differences were found for all types by ANOVA ($p<.05$). Lowest ADC was found for malignant lesions. Malignant and benign tumors were differentiated with 96% sensitivity and 94% specificity by an ADC threshold of 1.25 x10-3mm²/s. The same sensitivity/specificity was achieved for a two b-value combination. The optimal threshold was linearly decreasing for increasing b-value of combinations. Using low maximum b-values leads to overestimation of ADC (compartment effects) in all tissues but cysts (i.e.: ADC of 0/400 is ~26% higher than for 0/1000 in malignant lesions). An error of ±10% in the threshold was decreasing the specificity to 76% or sensitivity to 79%, respectively. Higher minimum b-values were additionally suppressing perfusion effects. For tumors a maximum CNR was found for 850 s/mm². The difference in CNR compared to neighbouring b-values was significant in benign/malignant lesions ($p<.05$), but not significant for malignant lesions when compared to b=1000 x10-3mm²/s ($p=.118$). While benign lesions exhibited an average 26% higher CNR than malignant lesions at 0 s/mm², the mean CNR at 850 s/mm² was 22% higher for malignant lesions than for benign. Investigations of the CV showed an increase of the precision for up to 850 s/mm² (i.e.: the CV between 0/400 and 0/850 dropped from 38% to 23%). The precision remained constant for b-values above. The advantage of fitting schemes with additional b-values was smaller (i.e.: fitting a combination of two b-values compared to ten b-values between b=0 and 1250 s/mm² changed the CV from 25.6% to 22.5% in malignant lesions).

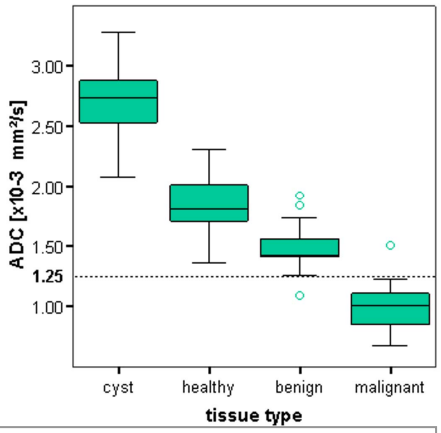

Fig. 2: Box-plot illustrates the differentiation of tissue types (benign, cystic, healthy, malignant) based on ADC as calculated from b=50/850 mm²/s with 95% accuracy for an ADC threshold of 1.25 x10-3 mm²/s.

Discussion and Conclusion:

High-resolution DWI is a fast way to add valuable functional information to conventional MR protocols which can improve the diagnosis of breast cancer. The application of our optimized DWI protocol at 3T provided a high diagnostic accuracy in our patient group of 69 women. However, diffusion schemes should be chosen carefully, as compartment effects and perfusion contributions may lead to differing ADC magnitude for different diffusion schemes and parameters should be optimized for good CNR and ADC precision/accuracy.

References:

[1] Yankeelov TE, et al. JMRI 2007; 25(1):1-13
[2] Wenkel E, et al. Acad Radiol. 2007; 14(9):1077-83
[3] Matsuoka A, et al. Radiat Med 2008; 26:15-20

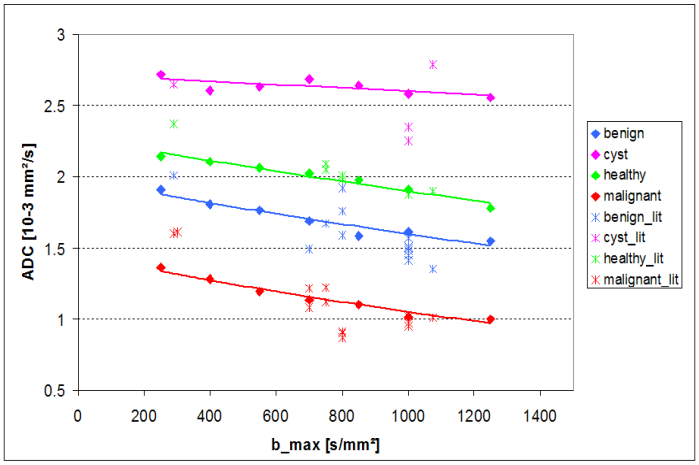

Fig. 3: Correlation of ADC with the choice of diffusion parameters. Both, our results (diamonds) and previously published ADC values (asterisks) show an overestimation of ADC for low b_max values. Our displayed results were calculated using two b-values (b=0 mm²/s + one b_max from 250 to 1250 mm²/s). A linear trend line correlates our measured ADC with b_max.