Breast Cancer Assessment Based on Perfusion Dependence in Diffusion Weighted Imaging using Different Monoexponential Fitting Schemes

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Target audience: Researchers and clinicians with an interest on perfusion and diffusion MRI techniques applied to breast cancer.

Purpose: The effect of perfusion on diffusion-weighted imaging (DWI) was first described by Le Bihan et al[1] by means of intravoxel incoherent motion (IVIM). Several studies have shown successful results in the use of the proposed method on separating the diffusion and perfusion component from DWI measurements for breast studies[2-5]. However, the biexponential model employed for IVIM requires the acquisition of a high number of low b-values, therefore increasing the scanning time and limiting the number of directions and averages in the clinical setting. In the present work we evaluate the potential of a simplified approach to obtain the perfusion effect on breast lesions from DWI.

Methods: Nine subjects presenting breast lesions were recruited. All patients were scanned at a Siemens 3T Skyra using a dedicated 16-channel breast coil. Diffusion-weighted images were acquired using a twice refocused spin echo sequence with an EPI readout: (TR/TE: 9300/85 ms; matrix: 90x90; in-plane res: 2x2 mm; slice thickness: 2.5 mm; b-values 0, 200 and 700 s/mm^2; 30 directions, and sagittal view). ROIs were manually placed on diffusion images covering the full extent of the lesion with assistance of DCE-MRI images for accurate delineation. ROIs of healthy fibroglandular tissue were obtained covering one slice from healthy volunteers (N=2) and patients using a slice without lesion (N=2). Simple cysts present in some of the patients were segmented as well and included for comparison (N=4). An in-house developed software using Matlab (The MathWorks, Natick, NJ) was employed to obtain the mean diffusivity (MD) of the lesion for three different monoexponential schemes using 2 diffusion weights each: (b = 0, 700 s/mm^2), (b = 0, 200 s/mm^2), and (b = 200, 700 s/mm^2). MD percentage change of the scheme with expected high perfusion effect (b=0 to 200) compared with the perfusion insensitive scheme (b=200 to 700) was calculated by: MD change (%) = 100*($MD_{0\text{-}200}$ – $MD_{200\text{-}700}$)/ $MD_{200\text{-}700}$. Unpaired Student's t-test was used for group comparisons and paired Student's t-test was employed to compare different MD fitting schemes using SPSS (Chicago, IL).

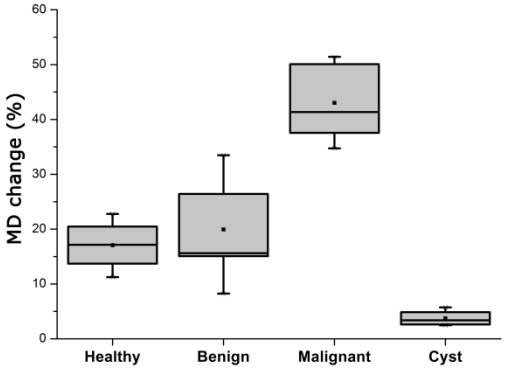

Figure 1. Boxplot of MD percentage change values obtained for each group**.**

Table 1. Summary of MD values and MD change (%) for each group and scheme.

Tissue	$MD_{0\text{-}700}$	$MD_{0\text{-}200}$	$MD_{200\text{-}700}$	MD change (%)
Malignant*	1.16 ± 0.08	1.51 ± 0.12	1.04 ± 0.07	43.02 ± 6.66
Benign*	1.69 ± 0.25	1.92 ± 0.32	1.60 ± 0.23	19.94 ± 8.11
Cyst	2.52 ± 0.17	2.57 ± 0.15	2.49 ± 0.19	3.73 ± 1.29
Healthy*	1.92 ± 0.11	2.16 ± 0.08	1.83 ± 0.13	17.08 ± 4.14

*Statistically significant (p<0.05) between $MD_{0\text{-}200}$ and $MD_{200\text{-}700}$. MD(x10^{-3} mm^2/s)

Results: Evaluation of the lesions by needle biopsy of the lesions or histology after resection resulted in four patients presenting 5 malignant lesions (invasive ductal carcinoma), and five patients presenting 7 benign solid lesions (fibroadenoma). MD values for each lesion as well as for each healthy ROI were obtained for the three schemes presented and MD percentage change was calculated as described in the methodology. The mean of the median values of each ROI under analysis are reported in Table 1. Differences between $MD_{0\text{-}200}$ and $MD_{200\text{-}700}$ were statistically significant for malignant (p<0.001), benign (p=0.002), and healthy tissue (p=0.004) and did not present significant changes for simple cysts (p=0.39). MD percentage change values showed significant differences when comparing malignant to benign and healthy (p<0.001), but no significance was found when comparing benign with healthy (p=0.56) (Figure 1).

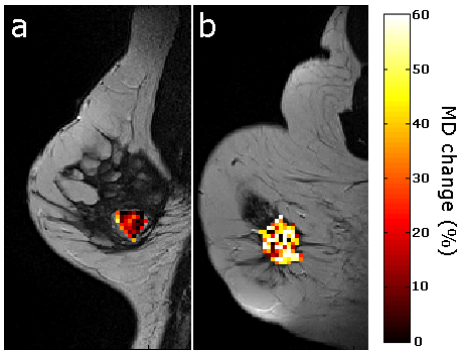

Figure 2. MD percentage change values obtained for **a:** fibroadenoma, **b:** invasive ductal carcinoma, overlaid on T_2-w images.

Discussion: Our results for MD values are in accordance with the expected diffusivity of the lesions and tissue studied. Significant differences when fitting to a low and to a high b-value for lesions and healthy tissue suggest there is an observable effect of perfusion on the diffusion measurements for these structures in accordance with findings using IVIM[2-4]. The negligible value of MD percentage change for cysts add robustness to the results, as simple cysts are known to present no vasculature. Our preliminary results suggest MD percentage change as an additional biomarker to distinguish malignant lesions from any other lesions and healthy tissue within the breast (Figure 2). In our protocol perfusion information derived from DWI is obtained by adding one extra diffusion weight (b=200 s/mm^2). This approach would be particularly useful when a separate protocol is not available or possible within a clinical timeframe. The main limitation is that, even enough information for lesion classification is obtained, our approach does not allow for a quantitative evaluation of perfusion, as it would be possible using IVIM. In addition, our results are limited by the small number of samples to date and ongoing recruitment will be used to validate these results.

Conclusion: In our study, we have presented how it is possible to obtain clinically relevant perfusion influence on diffusion measurements with the addition of only one extra weight factor to a DWI protocol.

References: 1. Le Bihan D, et al. Radiology, 1986. 2. Sigmund EE, et al. Magn Reson Med, 2011. 3. Liu C, et al. Eur J Radiol. 4. Iima M, et al. Proc ISMRM, 2013. 5.Thakur S, et al. Proc ISMRM, 2012.