Diffusion Tensor Imaging of the Breast: Preliminary Clinical Findings

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Introduction Diffusion tensor imaging (DTI) has been used primarily to elucidate microstructure and identify abnormalities in the brain, and has only recently begun to be investigated for discriminating cancer. A number of studies have shown promising results using ADC for tumor characterization and have demonstrated a negative correlation with cell density and tumor grade [1,2]. Several investigators have recently reported the value of measuring diffusion anisotropy to correlate with histologic findings of disease extent in prostate cancer [3,4]. In the breast, previous clinical studies using diffusion-weighted MRI (acquiring only the trace of the diffusion tensor) demonstrated encouraging differences between benign and malignant masses [5,6], however no studies to date have assessed the diagnostic value of measuring diffusion anisotropy in the breast. We hypothesized that disruption of the breast ductal network by invading cancer cells may cause alterations in water diffusion properties (both rate and directionality) in the tissue that will be reflected by DTI parameters. The purpose of this investigation was to determine and compare DTI values between invasive breast tumors, benign breast lesions, and normal breast tissue in human subjects.

Methods The study included 14 women who underwent breast MRI exams to evaluate known disease or suspicion of a breast abnormality. All patients received DTI scans as part of their clinical breast MRI exam, and institutional review board approval was obtained for this study. The women ranged in age from 33 to 65 years (median, 50 years). DTI was acquired at 1.5T using a dedicated 8-channel breast coil (GE Medical Systems, Milwaukee, WI) and a diffusion-weighted EPI sequence with ASSET parallel imaging technique (reduction factor =2). Scan parameters: TR/TE = 7s/71.5ms, 3 NEX, 192x192 matrix, 36x36cm FOV, 5mm slice thickness, no gap, and 2:40 min scan time. Diffusion gradients were applied in 6 directions with b= 0 and 600s/mm^2. DTI images were analyzed offline using DTI Studio processing software (Mori and Jiang, Johns Hopkins University). Lesions were identified on contrast-enhanced T1-weighted images acquired during the same exam, and regions of interest (ROIs) were defined on corresponding combined diffusion-weighted images. Several DTI parameters were measured including fractional anisotropy (FA), apparent diffusion coefficient (ADC), and three tensor eigenvalues (λ_1, λ_2, λ_3). Example images and parametric maps are shown in Fig 1. ROIs were also measured in normal appearing fibroglandular tissue from the contralateral breast for comparison.

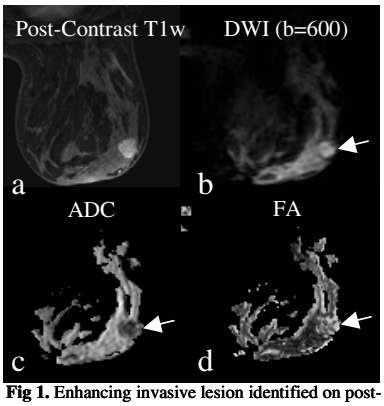

Fig 1. Enhancing invasive lesion identified on post-contrast T1-weighted imaging (a) shows hyperintensity on diffusion-weighted images (b), reduced ADC (c), and increased FA.

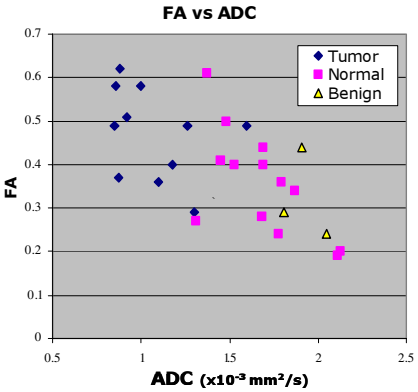

Fig 2. Plot of FA versus ADC for invasive tumors (n=11), benign lesions (n=3), and normal tissue from contralateral breasts (n=14).

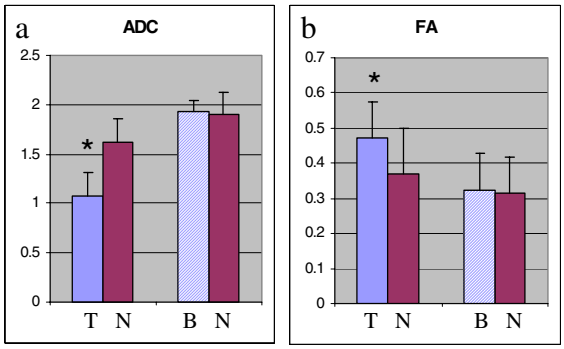

Fig 3. Mean ADC values (a) in units x10^{-3}mm^2/s, and FA values (b) for tumor (T), compared to normal tissue (N), and benign lesions (B). For both tumor and benign, the corresponding normal tissue measures were taken from uninvolved tissue in the contralateral breast of the same subjects. Tumors were significantly lower in ADC (p=.0001) and higher in FA (p=.046) than normal tissue.

Results The study group included 11 invasive ductal carcinomas, and three benign lesions (2 enhancing fibroadenomas, 1 nonenhancing cyst) as determined by pathology or follow-up. ADC was significantly reduced in the invasive lesions (p=0.0001, t-test) compared to normal tissue, and was also lower than that of the benign lesions in our study (small n precluded statistics), as has been reported previously, Fig. 2. Diffusion anisotropy values, not previously reported in breast lesions, also demonstrated differences. In general, the invasive tumors exhibited increased FA with respect to normal breast parenchyma (p=0.046), Fig 3. Tumors had a mean FA of 0.47±0.10 and mean ADC of 1.07±0.24 mm^2/s compared to normal tissue (FA = 0.37±0.13, ADC = 1.62±0.24 mm^2/s). The benign lesions in our study exhibited ADC and FA values comparable to that of normal tissue in the contralateral breast but notably different than tumor values, Fig. 3, (however, small n precluded statistical evaluation).

Discussion To our knowledge, this is the first report of normative DTI anisotropy values in the breast, as well as measurements in human breast lesions. These preliminary data suggest that DTI may provide additional useful information over standard diffusion-weighted imaging. More work must be done to further evaluate the clinical utility of anisotropy measures for improving the diagnosis of breast lesions.

References

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