Simulations of the Impact of TWIST View Sharing on the Measured Enhancement in Breast DCE MRI

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Introduction Dynamic contrast-enhanced MR imaging (DCE-MRI) is an important diagnosis tool for breast cancer. K-space data sharing techniques [1-2] such as Time-resolved angiography With Stochastic Trajectories (TWIST) can be very helpful [3-5] in DCE-MRI to balance the requirements of high spatial and temporal resolutions. However, sharing k-space data from different time points of dynamic contrast enhancement will impact the measured signal intensity [6-7]. To study how k-space data sharing strategy affects the measured contrast uptake in breast cancer and optimize imaging parameters, we conducted a simulation similar to that described by Song [8], to estimate the error due to k-space data sharing on the enhancement and to evaluate its impact on breast cancer diagnosis.

Methods A simulated breast 'phantom' has 448x448x16 isotropic voxels and dimensions of 36x36x13 cm. Enhancing spherical lesions of different diameters and three types of contrast enhancement curves (persistent, plateau and wash-out as defined by ACR-BIRADS description [9], shown in Fig. 2) were generated and considered as the "True" lesion enhancement while normal breast tissue was assumed to have no enhancement. As in typical clinical breast DCE-MRI protocols, k-space data at six time points (1 pre- and 5 post-contrast) were generated by Fourier transform of the phantom data and then sampled with 80% resolution in two phase encoding directions. Images were reconstructed with and without k-space data sharing. A k-space data sharing strategy similar to TWIST and ECTRICK was used, i.e. the *k*-space data was divided into a central region A and a peripheral region B [8]. In this study, the ratio of the k-space views in region A and total k-space views, pA, was varied from 0.2 to 0.5 while the fraction of the k-space views region B that is re-sampled at each time point, pB, was kept at 0.5, i.e. 50% of peripheral k-space views were the same views simulated for previous time point. Enhancement curves are calculated by averaging the enhancement of all voxels within a spherical ROI centered in the lesion at each time point. Since clinical diagnosis is usually based on the 'worst' area in a lesion, a 3 mm diameter ROI at the center of the lesion was also used in addition to a whole lesion ROI.

Results Fig.1 shows the signal intensity distribution in a tumor from images with/without k-space data sharing at the first post-contrast time point. There is noticeable change in signal intensity distribution due to k-space data sharing. Fig. 2 shows the simulated enhancement for three different types of 6 mm lesion compared with their 'True' enhancement. The under-estimation for the first post-contrast time point was 10% in the plateau and 12% in wash out curves, while the type of curves can still be correctly determined. Fig. 3 and 4 shows the deviation from wash-out curves for various lesion sizes with pA=0.33 and for various central k-space region A fractions with lesion size=6mm, respectively. With pA > 0.33 and pB=0.5, for lesion diameter > 5 mm, the type of enhancement curve can be correctly determined using signal average from a 3mm ROI.

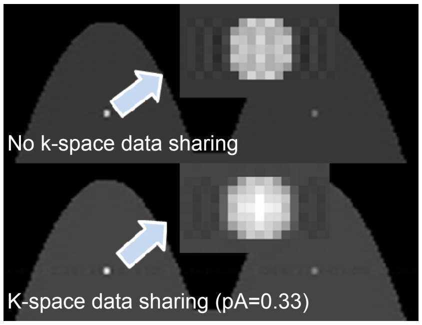

Figure 1. A 6 mm tumor in images with and without TWIST data sharing (pA = 0.33).

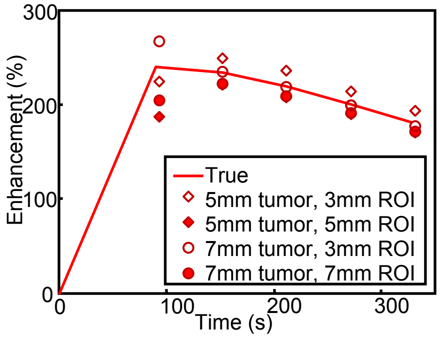

Figure 3. Enhancement in whole tumor or 3mm ROI. pA = 0.33.

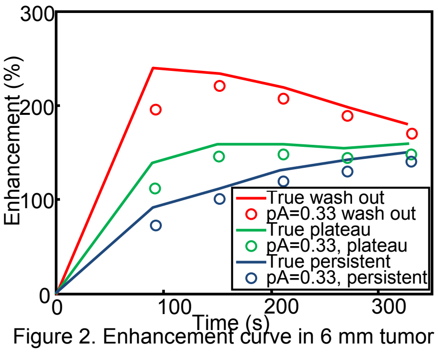

Figure 2. Enhancement curve in 6 mm tumor (all three types of curves, pA=0.33)

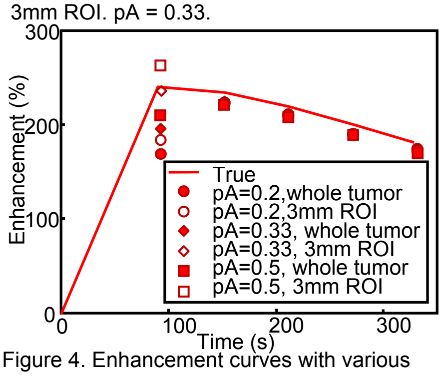

Figure 4. Enhancement curves with various pA. Tumor diameter is 6mm.

Discussion Our simulations show that k-space data sharing can cause errors in the measured enhancement curve of breast lesion especially when the lesion is small. For tumors with a diameter of more than 5 mm, the measured enhancement curve type can be preserved under certain conditions. According to ACR-BI-RADS, enhancement of less than 5 mm (foci) is usually not followed-up with intervention [9-10]. Therefore, using a k-space data sharing strategy like TWIST, with greater than 33% central region fraction and more than 50% peripheral region sampling density, will not significantly distort the enhancement curve and therefore adequate for clinical breast DCE MRI.

These results and further follow-up studies may provide guidance for optimizing clinical protocols when k-space data sharing is applied and be helpful in understanding and improving k-space data sharing strategies in breast MRI. Although TWIST strategy was used in this study, this method can be used to analyze other k-space data sharing methods.

Reference 1.van Vaals, J.J., et al., J Magn Reson Imaging, 1993. **3**(4): p. 671-5. 2.Parrish, T. et al., Magn Reson Med, 1995. **33**(3): p. 326-36. 3.Herrmann, K.-H., et al., *ISMRM* 2010: p. 2503. 4.Janka, R., et al., *ISMRM* 2010: p. 4553. 5.Laub, G., et al. *ISMRM* 2007. p. 3058. 6. Bishop, J.E., et al., J Magn Reson Imaging, 1997. **7**(4): p. 716-23. 7.Krishnan, S. et al. J Magn Reson Imaging, 2004. **20**(1): p. 129-37. 8. Song, T., et al., Magn Reson Med, 2009. **61**(5): p. 1242-8. 9.Agrawal, G., et al., Cancer, 2009. **115**(7): p. 1363-80. 10. ACR, *Implementing the ACR BI-RADS® – MRI in Clinical Practice*. 2003, ACR BI-RADS®–MRI Lexicon Committee. p. 3-4.