Assessment of Four Different DWI Pulse Sequences Used for Breast Imaging

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Introduction Recent improvements to echo planar imaging (EPI) sequences, coupled with the widespread use of parallel imaging techniques, resulting in very fast acquisition times and reduced eddy current artefacts, now allow DWI to be undertaken in body areas such as breast, pelvis, liver and kidneys. DWI of the breast can be problematic since a large FOV is required over non-uniform tissue which includes a large amounts of air. A number of different schemes are employed by a variety of DWI pulse sequences to provide diffusion weighting and to null the signal from fat. At our institution we have access to four different EPI DWI schemes – product EPI DWI, STIR DWI, VECTOR DWI and STIR VECTOR DWI. The STIR sequence differs from the product EPI DWI sequence since a inversion pulse is utilised to null the signal from fat. This has the advantage of been insensitive to local B0 inhomogeneities that are more likely to occur in large FOV body DWI. Whereas the VECTOR sequence differs from the product scheme since all diffusion gradients are applied simultaneously as opposed to the sequential (AP, RL, SI) application in product EPI DWI. The aim of this work was to assess these sequences with both phantom and *in vivo* data to determine which sequence was best suited to breast work.

Methods All imaging was undertaken on a GE 3.0T HDx scanner. Imaging parameters for phantom experiments were as follows: TR/TE 2000/minimum ms, TI 180ms (for STIR sequences only) FOV 160mm, slice thickness 10mm, matrix 128 x 128, *b*-values 0 and 700s/mm^2. To ensure the same number of measurements for both b = 0 and b = 700 s/mm^2 images two experiments were run of each DWI scheme. First experiment, averages set to 4 for all diffusion sequences thereby ensuring all b=0 s/mm^2 images are collected with 4 measurements. Second experiment, averages set to 4 for product EPI DWI and STIR DWI since these sequences applied diffusion gradients in 3 orthogonal planes resulting in 12 measurements for b = 700 s/mm^2. For VECTOR and VECTOR STIR DWI sequences since all 3 diffusion gradients are applied simultaneously the averages were set to 12 again ensuring the number of measures was 12 for b = 700 s/mm^2 images. SNR and GSR were calculated.
Parameters for *in vivo* experiments were as follows: TR/TE 7000/minimum ms, TI 180ms (for STIR sequences only), FOV 380mm x 380mm, slice thickness 7mm, matrix 128 x 128, *b*-values 0 and 700 s/mm^2, averages 5 (product EPI DWI and STIR DWI) or 10 (VECTOR or VECTOR STIR) resulting in a scan time of 2 minutes 20 seconds for each scheme. Since repeating the DWI sequence twice *in vivo*, as in the phantom studies, for each diffusion scheme was impractical a pragmatic decision was taken to maintain a standard scan time and correct the SI by multiplying by the square root of the factor difference in the number of measures between sequences. Quantitative SNR and qualitative assessment of image quality was then undertaken by two experienced readers (>10yrs MR experience each) in a doubly blinded fashion (to each other and imaging parameters); readers were asked to rank each pulse sequence based on the following criteria: level of fat signal contamination, geometric distortion, and level of aliasing.

Results Phantom results revealed that the application of an inversion pulse in the STIR and VECTOR STIR schemes negativity impacted on signal intensity and therefore SNR, whereas GSR remains fairly constant throughout, see Fig Ia & Ib. *In vivo* studies in 11 patients also demonstrated a reduced SNR for STIR and STIR VECTOR sequences with one-way analysis of variance revealing a significant difference between the different diffusion sequence b = 700s/mm^2 ($p<0.013$), see Fig. Ic. VECTOR and STIR VECTOR schemes demonstrated a consistently lower ADC than both product EPI DWI and STIR DWI with one-way analysis of variance again revealing a significant difference between the sequences ($p<0.001$), see Fig Id. Agreement between the readers was determined to be 'good' based on the Kappa gamma score of 0.628. Based on the mean scores (lowest = best) for each pulse sequence from each reader the diffusion schemes were ranked in the following order: STIR VECTOR (1.53 and 1.63), STIR (2.00 and 1.94), VECTOR (3.20 and 3.19), and product EPI (3.27 and 3.25). The results of a Friedman test revealed the differences between the pulse sequence scores to be significant ($p<0.001$) for both readers.

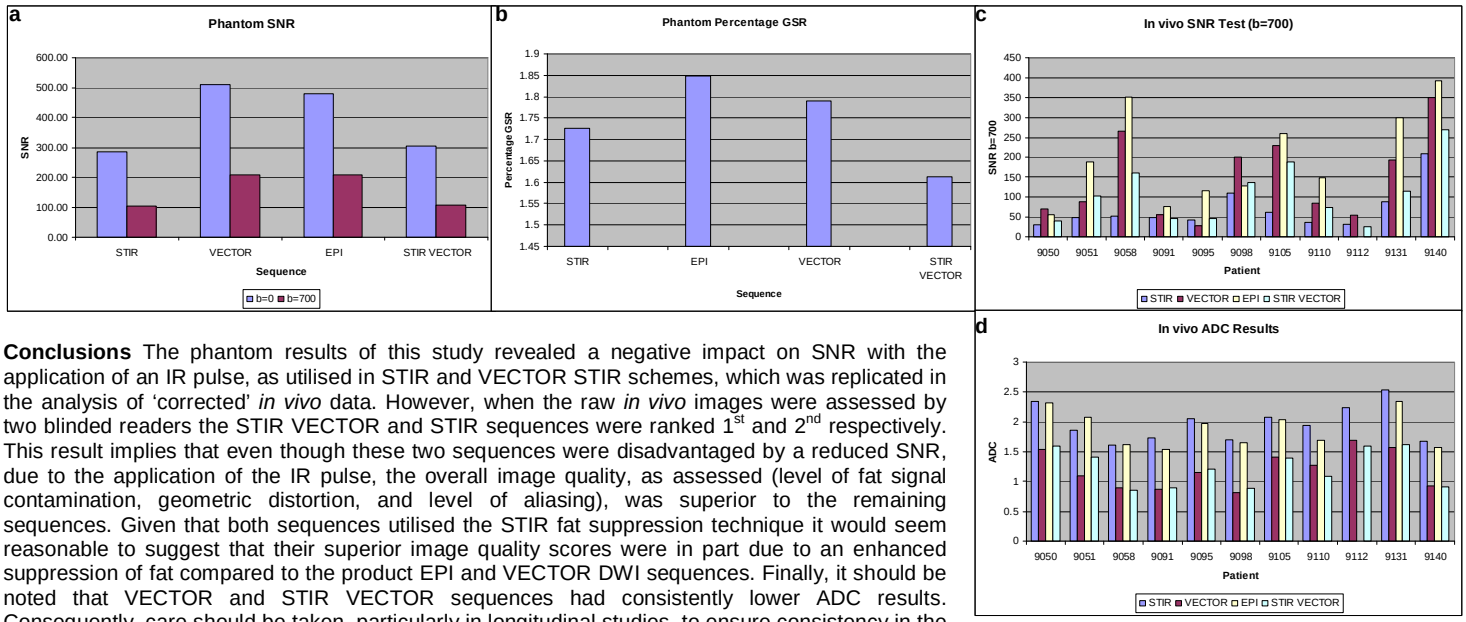

Figure I

Conclusions The phantom results of this study revealed a negative impact on SNR with the application of an IR pulse, as utilised in STIR and VECTOR STIR schemes, which was replicated in the analysis of 'corrected' *in vivo* data. However, when the raw *in vivo* images were assessed by two blinded readers the STIR VECTOR and STIR sequences were ranked 1st and 2nd respectively. This result implies that even though these two sequences were disadvantaged by a reduced SNR, due to the application of the IR pulse, the overall image quality, as assessed (level of fat signal contamination, geometric distortion, and level of aliasing), was superior to the remaining sequences. Given that both sequences utilised the STIR fat suppression technique it would seem reasonable to suggest that their superior image quality scores were in part due to an enhanced suppression of fat compared to the product EPI and VECTOR DWI sequences. Finally, it should be noted that VECTOR and STIR VECTOR sequences had consistently lower ADC results. Consequently, care should be taken, particularly in longitudinal studies, to ensure consistency in the DWI scheme utilised throughout studies.