Effect of the Spatial Resolution of A-priori Data on the Quality of Single-Point Dixon Fat-Water Images

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Introduction: Single point Dixon (SPD) techniques have been suggested as a method for fat/water (F/W) separation in dynamic contrast enhanced breast MRI [1,2,3]. In SPD, the phase information needed to separate the fat and water signals is measured only once prior to contrast injection and is assumed to be stable throughout the exam. This *a priori* data is then used to reconstruct fat and water images from a series of images acquired with a quadrature TE during and after Gd-DTPA injection. In this work, the effect of reducing the spatial resolution of the *a priori* phase information on SPD images is examined in detail, considering both noise performance and the quality of the F/W separation.

Theory: In our implementation of SPD, two in-phase images C_1 and C_2 are obtained in order to determine the field map, ΔB_o, and the static phase, ϕ_o (Figure 1). A quadrature image (I) is then obtained using a TE_I for which the fat/water phase angle is an odd multiple of $\pi/2$. Finally, I is demodulated using ΔB_o and ϕ_o to obtain water and fat images from the real and imaginary channels, respectively.

Starting with measured standard deviations (SD) of σ_P for C_1 and C_2, and σ_Q for I, standard error propagation techniques were used to calculate the noise in the separated fat and water images. The SD's in the water (σ_{WW}) and fat (σ_{WF}) regions of the water image were calculated separately, as were the equivalent SD's (σ_{FF} and σ_{FW}) in the fat image. The results of these error calculations indicate that, to the lowest non-zero order, σ_{WW} and σ_{FF} are equal to σ_Q, while σ_{WF} and σ_{FW} depend on both σ_P and σ_Q. For example,

$$\sigma_{WF} = \sqrt{\sigma_Q^{\,2} + \sigma_P^{\,2} f} \quad \textit{where } f = \frac{\sqrt{(TE_I - TE_{C1})^2 (F/C_2)^2 + (TE_{C2} - TE_I)^2 (F/C_1)^2}}{|TE_{C1} - TE_{C2}|}$$

where F is the unsuppressed fat signal in I. Although σ_Q is fixed by one's choice of scan parameters for the dynamic scans, σ_{WF} may be decreased by reducing σ_P. Increasing the NEX of C_1 and C_2 will reduce σ_P but with an unacceptable time penalty. On the other hand, lower spatial resolution decreases the scan time while increasing SNR. Since ΔB_o and ϕ_o generally are slowly varying in space, significant reductions in resolution should be compatible with successful SPD fat-water separation.

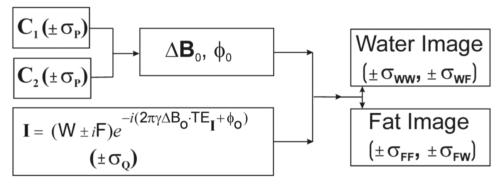

Figure 1: *Reconstruction of water (W) and fat (F) images using a SPD technique. The standard deviation associated with each image is indicated in brackets. For the water image, there are two standard deviations defined, one for water regions and one for fat regions (σ_{WW},σ_{WF}). For the fat image, the standard deviations in the fat and water regions are σ_{FF} and σ_{FW} respectively.*

Methods: Images of a two-compartment fat-water phantom were obtained with a bird-cage head coil in a GE 1.5T MRI scanner. A 3D spoiled gradient echo sequence was used with: α=30°, 20cm FOV, $TE_1/TE_2/TE_3$=9.0ms/4.5ms/3.4ms, 256^2 matrix, 3mm slice thickness, 1NEX. Lower resolution C_1 and C_2 images (imaging matrices 256^2 to 16^2, pixel sizes 0.78-12.3mm per side) were simulated by applying progressively narrower Hamming filters to the k-space data. For each resolution, ΔB_o and ϕ_o were determined and combined with the full resolution (256^2) I image to reconstruct sets of separated fat and water images. The signal SD's σ_{WW}, σ_{WF}, σ_{FW} and σ_{FF} were calculated within appropriate regions in these water and fat images. In another experiment, non-contrast enhanced SPD breast imaging was performed on a healthy volunteer. A dedicated 4-coil breast array was used, but otherwise the same sequence, parameters, and F/W reconstruction techniques were used as described above for the phantom experiment.

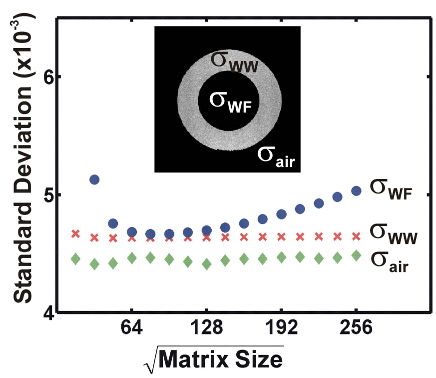

Figure 2: *Pixel standard deviations in different regions of water images of a fat-water phantom are shown as a function of phase image matrix size. A typical water image is shown to clarify the nomenclature. Field of view was*

Results: Figure 2 illustrates the effects on phantom water images of reducing the resolution of the phase-mapping images C_1 and C_2. For most matrix sizes, the SD in the fat region (σ_{WF}) decreases as resolution is reduced, while in the water region σ_{WW} is roughly independent of resolution, in agreement with the theoretical predictions above. For matrices smaller than 64^2, both σ_{WF} and σ_{WW} increase, indicating a breakdown of fat-water separation. Similar results were obtained for the fat images. In Fig 3, breast SPD water images and corresponding ΔB_o maps are shown for C_1 and C_2 matrices of 256^2, 64^2 and 16^2. Fat-water separation is excellent in the first two resolutions, but some breakdown of fat-water separation is seen at the 16^2 matrix size, especially in areas of high susceptibility variation (see arrows). Phantom and breast studies both indicate that F/W separation begins to fail when the voxel size in the ΔB_o and ϕ_o images exceeds about $(3\text{mm})^2$. Extremely low resolution maps no longer reflect the rapid field variations at tissue or compartment boundaries.

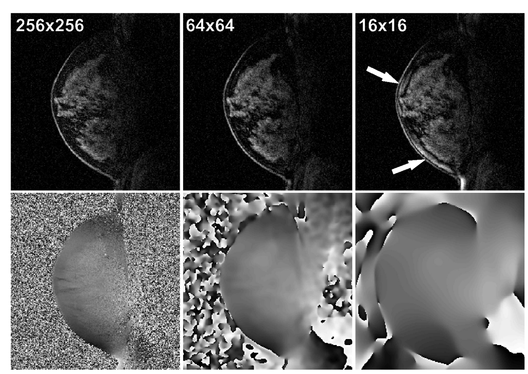

Figure 3: *SPD technique applied to human breast imaging using three different phase map resolutions. Top row: water images. Bottom row: ΔB_0 images. Regions of poor fat-water separation are indicated by white arrows.*

Conclusion: Decreasing the spatial resolution of the phase-mapping images C_1 and C_2 improves F/W separation, as indicated by lower noise standard deviations (σ_{FW} and σ_{WF}) in the suppressed signal regions of SPD water and fat images. Lower resolution images take less time to acquire, thus reducing the overall examination time. This work shows that it is possible to reduce the size of the acquisition matrix for the phase imaging scans to about 64^2 (voxel size $(3\text{mm})^2$) without compromising the quality of fat-water separation.

References:

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[2] Huanzhou Y et al. Proc. ISMRM **13** (2005),2390.
[3] Yu H et al. Mag.Res.Med., **55**:413-422 (2006).