Optimal K-Space Acquisition Reordering for Intermittent Fat Saturation in Breast MRI

K. L. Desmond[1], E. Ramsay[2], D. B. Plewes[1,2]

[1]Medical Biophysics, University of Toronto, Toronto, Ontario, Canada, [2]Imaging Research, Sunnybrook and Women's College Health Sciences Centre, Toronto, Ontario, Canada

Introduction

Breast imaging is typically aided by fat suppression. Fat suppression attempts to null any signal arising from fat, which appears isointense to Gd-DTPA enhanced regions in T1-weighted MR imaging. Several methods have been developed to achieve fat suppression, namely subtraction, chemically selective fat saturation, and variations upon the Dixon method[1]. Fat saturation is preferable due to its robustness to small movements, and relatively small extensions to the imaging time. However, this increase in imaging time is not negligible; the chemically selective rf pulse and spoiler gradients add approximately 10ms to every TR. This is detrimental to imaging applications which have strict temporal requirements, such as dynamic contrast-enhanced MRI, and/or when the area of interest is very large, as in screening procedures. In these applications, the TR is typically as short as 6ms without any fat suppression, so the introduction of saturation more than doubles the required imaging time. There is also a limit to the total imaging time imposed by the window of time in which the contrast agent is effective, approximately 10 minutes. We demonstrate a method of partial-k-space fat suppression[2] for 3D scans which significantly reduces the extension in imaging time while producing images which are visually equivalent to those produced with the conventional full-k-space saturation techniques.

Method

The (k_y,k_z)-profiles are ranked according to their contribution to reducing the observable fat signal in the reconstructed image. This can be presupposed (as in elliptic-centric acquisitions) or derived based on *a priori* information of the object being imaged (k-space ranking method[3]). We follow an elliptic-centric ranking for simplicity. The number of TR periods, "n", between applications of fat saturation is chosen depending on the desired temporal resolution. A k-space reordering map is constructed by dividing the ranked k-space points into n sections (see Figure 1 for an example with n=4). The numbers in each section specify the number of TR periods which have elapsed after the fat saturation pulse, with the most centric (k_y,k_z)-profiles acquired first (or when the fat signal is completely nulled). The state of the fat magnetization in each section can be modeled by the Bloch equations. We compare this "reordered" method to a less efficient "biphasic" approach[4]. The biphasic method acquires k-space points in order of their ranking, and fat saturation is applied to only the first nz*ny/n of the points (where nz and ny describe the resolution in the z and y directions respectively).

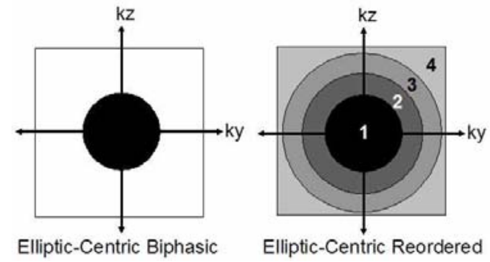

Figure 1 - *Biphasic and Reordered K-space maps for an example 25% fat suppression. Numbers in each section of the reordered map indicate the relative timing of the acquisition of these (ky,kz) profiles after the fat saturation pulse. Shading represents the amount of fat signal seen by each region (black = none, white = full recovery).*

Experiments were performed on a phantom in a GE Signa 1.5T scanner in a standard head coil with the following imaging parameters: TE: 1.976 ms, TR: 6ms without fat suppression, (18ms with fat suppression), FOV: 20cm, resolution: 128x128x16, flip angle = 30. The phantom consisted of a plastic bottle containing both oil and water, immersed in doped water to avoid susceptibility artifacts. In-vivo experiments were performed with a custom designed prone breast bed (Sentinelle Medical) with the following scan parameters TE: 3.288 ms, TR: 10ms without fat suppression (21ms with fat suppression), FOV 20cm, resolution: 256x256x16, flip angle = 10 degrees.

For both the phantom and the in-vivo experiments, a series of images were acquired in which the frequency of application of the fat saturation pulse was varied from being applied every TR to every 100th TR. The effectiveness of the fat suppression is determined by the reduction in root-mean-square (rms) error between the partially fat suppressed image and one which is fully fat suppressed.

Results

Figure 2 characterizes the reduction in RMS error in the phantom images as the number of fat saturation pulses are varied from nz*ny to 1% of this value for both the elliptic-centric biphasic and elliptic-centric reordered methods. The reordered case achieves significantly better fat suppression for lower numbers of fat saturation pulses than the biphasic case. Figure 3 displays a characteristic slice from a 3D breast image. This 3D image was reproduced for 25, 10 and 1% fat saturation to compare the two ordering methods.

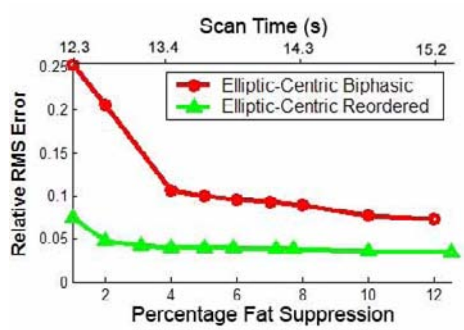

Figure 2 - *Experimental phantom data showing RMS error as a function of percentage fat saturation for the reordered method. The results for the biphasic method are shown for comparison.*

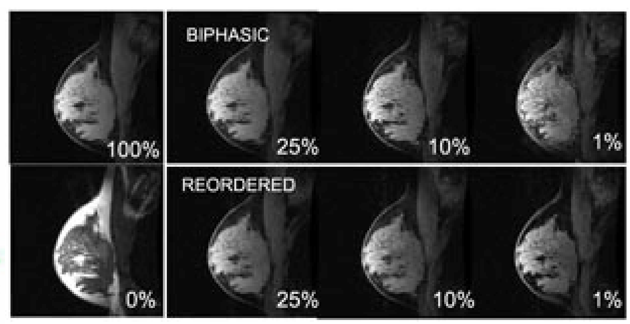

Figure 3 – *Breast images with varying percentage fat suppression for both the biphasic and reordered methods. Note the preservation of the fat suppression in the reordered images. The images with full fat suppression and no fat suppression are shown for reference.*

Discussion

Using the reordered method we could achieve excellent fat suppression even when only 1% of k-space received a fat saturation pulse. This corresponds to a reduction in the extended image time of 99%, that is, the overall scan time is only 1% longer than an equivalent scan without any fat saturation. This allows for the completion of double the number of 3D images compared to full fat saturation. We have achieved a substantial improvement in the temporal resolution available for fat suppressed images. This technique could improve the temporal resolution of dynamic contrast enhanced 3D images obtained as part of a breast cancer screening procedure.

References

[1] Dixon WT. *Radiology* **153**: 189-94 (1984)
[2] Flask CA, *et al.*, *JMRI* **18**: 103-12 (2003)
[3] Desmond, K, *et al.*, *ISMRM Proceedings* ***13*** (2005) 1850
[4] Murray C, *et al.*, *SMRT Proceedings* (2004)