K-Space Ranking for Optimal Fat Suppression in Dynamic Breast MRI

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Introduction

Fat suppression is critical to aid in differentiating Gd-DTPA enhanced breast lesions from bright fatty structures which would be seen in gradient recalled imaging sequences. Several methods have been developed to correct for this effect, including subtraction, chemically selective fat saturation, and variations of the Dixon method[1]. Subtraction suffers from motion artifact while the remaining two methods involve significantly increased scan time. This is not ideal since many lesions are characterized by the dynamic evolution of the signal while monitoring the effects of the injected gadolinium. As a large number of slices are required for 3D screening procedures, increasing scan time reduces the number of dynamic scans which can be acquired within the window of time in which the tumor contrast is maximum (approx. 10 mins). Partial k-space fat suppression has been shown to be effective in reducing scan time without obviously affecting the quality of the MR images[2,3]. In this work, we demonstrated that there exists an optimum set of k-space points which, when fat suppressed, will lead to the greatest amount of fat suppression overall while minimizing the acquisition time. This set can be derived from *a priori* knowledge of the fat suppressed and non-fat suppressed k-space of the breast, which would be acquired prior to the contrast-enhanced dynamic imaging. This assumes that there is no large-scale movement between the acquisition of this *a-priori* data and the actual imaging post contrast agent injection.

Method

The effects of partial fat suppression were simulated by combining k-space data from two 3D breast image data sets obtained with and without full fat suppression. A 3D SPGR sequence (TE/spatial res/flip angle =4.3ms/32x256x256/30°, on a 1.5 T GE Signa) was used with the minimum TR for chemical fat saturation of 17ms which dropped to 8 ms without fat suppression. This resulted in a scan time of 1.1 minutes without fat suppression or 2.3 minutes with fat suppression. An iterative algorithm was used to determine the optimal k-space ranking in the ky-kz plane according to two properties: the contribution of that k-space point to the overall reduction in fat signal and whether the point is adjacent to points which have already been ranked (with the central point assigned first rank). The effectiveness of the fat suppression is determined by the reduction in root-mean-square (rms) error between the partially fat suppressed image and that which is fully fat suppressed. The number of fat suppression pulses was varied from 1 to 256*32 pulses which were distributed throughout k-space according to their optimal k-space ranking. The Bloch equations were used to simulate the effects of remnant longitudinal fat magnetization arising from these intermittent fat saturated pulses.

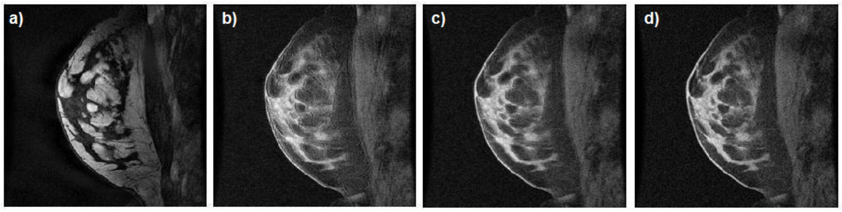

Figure 1 – 3D Breast images showing a) 0% b) 9% c) 20% d) 100% fat saturation using k-space ranking method. The relative rms errors for these images are 100%, 10%, 5% and 0% respectively.

Results

The image quality as a function of overall scan time arising from differing numbers of k-space points receiving fat suppression are presented in Figure 1. No noticeable degradation of the image quality is apparent above a 5% rms error. The complete range of rms error as a function of scan time is shown in Figure 2. For comparison, the same curve is plotted using the results of a simulated elliptic centric method with the same data. This shows that scan times are substantially reduced with k-space ranking compared to elliptic centric fat suppression for the same overall image error. The 5% error threshold was achieved with a scan time of 1.35 min for k-space ranking compared to 2.25 min for elliptic centric ranking.

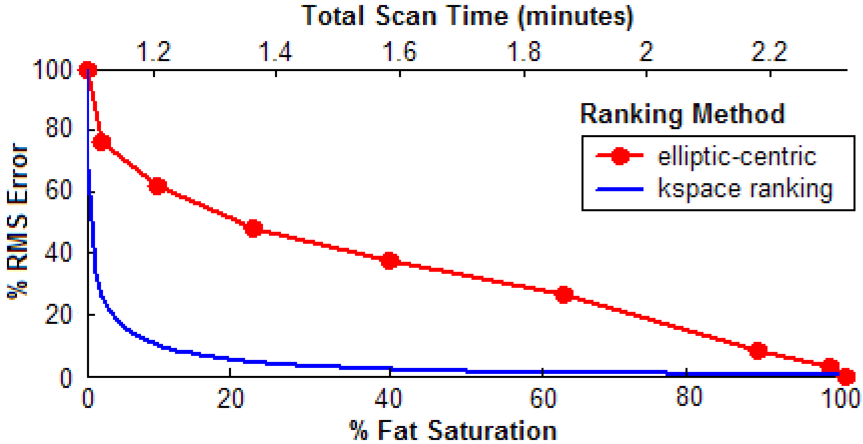

Figure 2 - Error as a function of scan time for the following imaging parameters: TRnofs/TRfs/slices/res/flip angle = 8ms/17ms/32/256x256/30. Increased scan time corresponds to a greater percentage of k-space points receiving fat suppression.

Discussion

With the k-space ranking method and an allowance of 5% rms error, 7 full image sets can be acquired in 10 mins as opposed to only 4 for the elliptic centric method and for full k-space fat saturation. As a result, there is more dynamic information available to classify lesions which may be identified in the breast screening. Any reductions in scan time will also correspond to a reduction in the potential for motion artifacts. One may also use the time savings to increase spatial resolution of fat suppressed images.

References

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