Combinatorial fat suppression for Diffusion Weighted Imaging at 3.0T

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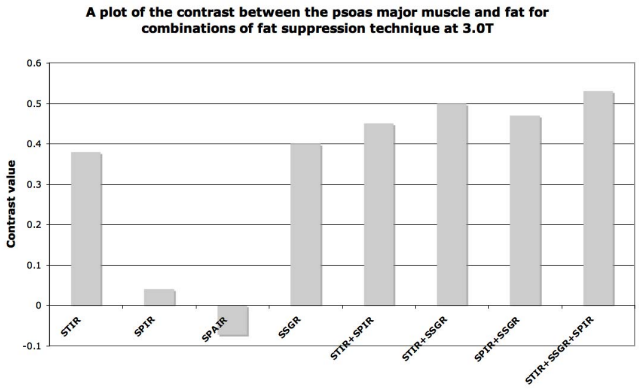
Introduction: Diffusion weighted imaging (DWI) sequences require on reliable fat suppression techniques to remove lipid signal from the images. In the detection of small lesions using DWI, high intensity chemical shift artifacts may reduce the sensitivity of the technique. Fat suppression techniques may be separated into three categories: a) those which utilize the difference in the Larmor frequency of water and fat such as SSGR [1], b) those which utilize the difference in spin-lattice relaxation times (T_1) of water and fat such as STIR, and c) those which use both these properties such as SPIR and SPAIR [2]. Whilst these techniques have been used successfully in conjunction with DWI at 1.5T, their use in scanners operating at 3.0T remains challenging [3]. An often-misleading assumption is that higher field strengths should improve the fat suppression due to larger differences in T1 and Larmor frequency between fat and water [2]. However, high field strengths are associated with increased B_0 inhomogeneities, which are observed to degrade the quality of fat suppression, particularly over large fields-of-view (FOVs). The objective of this study was to investigate the use of STIR, SPIR, SPAIR and SSGR alone and in combination for use in fat suppressed whole body DWI at 3.0T.

Method: ***Acquisition***: Diffusion-weighted images of the upper pelvis and abdomen of five volunteers (3 male, 2 female) were acquired axially using a 3.0T MR system (Achieva; Philips Healthcare, Best, The Netherlands) at b-values of 0 and 800 s mm^{-2} utilizing SSGR, SPIR, SPAIR and STIR alone and in combination. The inversion time used for STIR sequences was optimized subjectively in one volunteer by a consultant radiologist to 230ms. All images were acquired using 3 averages over a 128 x 128 matrix, 380mm field of view with final image resolution 1.5mm x 1.5mm and a slice thickness of 5mm. Note that due to time restrictions, not all fat suppression techniques could be tested on a single volunteer.
Analysis: For each of the four remaining volunteers, 3-5 image slices were chosen such that regions of interest (ROIs) could be drawn on b-0 images around the Psoas Major muscle (ROI_{pm}) and also around the perimeter of the body (ROI_{fat}) and then translated to the b-800 images (see figure 2(a)). Data outside ROI_{fat} was considered to represent fat under the assumption that it arose from chemical shift of fat into the background. Noise statistics were calculated in areas without fat signal and pixels with values less than the noise mean plus two standard deviations were ignored. Data for all slices were combined for each suppression method and the mean (μ_{pm} and μ_{fat}) and standard deviations (σ_{pm} and σ_{fat}) calculated. Contrast between the mean values for pm and fat were calculated using the Michelson definition: $c = (\mu_{pm} - \mu_{fat})/ (\mu_{pm} + \mu_{fat})$.

Results: A contrast bar diagram (Fig 1) shows that SPAIR provided the worst contrast with negative values, and so was not considered for combination with other techniques. As may be expected, using more than one suppression technique improves the saturation of fat signal, although this generally involves an increase in the total acquisition time (roughly a 6 fold increase for STIR+SSGR+SPIR compared to SSGR alone). A major limitation of using any of the techniques involving SSGR was the water signal attenuation at various locations within the image as demonstrated in figure 2.

Conclusions: Our results indicate that combination techniques provide improved fat suppression although this results in longer acquisition times. Best results were obtained when using SSGR in combination with STIR although SSGR diminished water signal at various positions in the body, which could lead to inaccurate measurements. The SSGR method is more sensitive to water off-resonance than SPIR or STIR as through-plane chemical shift begins to occur for off-resonant water species as well as for lipid. Larger water off-resonances are characteristic of the larger B_0 inhomogeneities associated with high field strengths. Improvements in shimming techniques are required in order to use these suppression techniques reliably over large fields of view. A good method of fat suppression that does not seem to be affected in the same way is STIR in combination with SPIR, although parameter optimizations are necessary to improve the level of fat suppression.

Figure 1



References: [1] Park *et al.*, Magn. Reson. Med., 4(6):526-36, 1987.
[2] Default *et al.*, Radiographics, 19(2):373-82, 1999
[3] Takahara *et al.*, Proc 17th Annual Meeting ISMRM 2009 (2642)

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Figure 2(a)

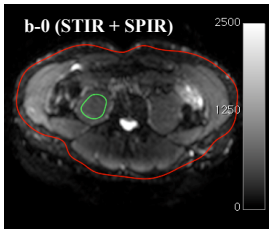
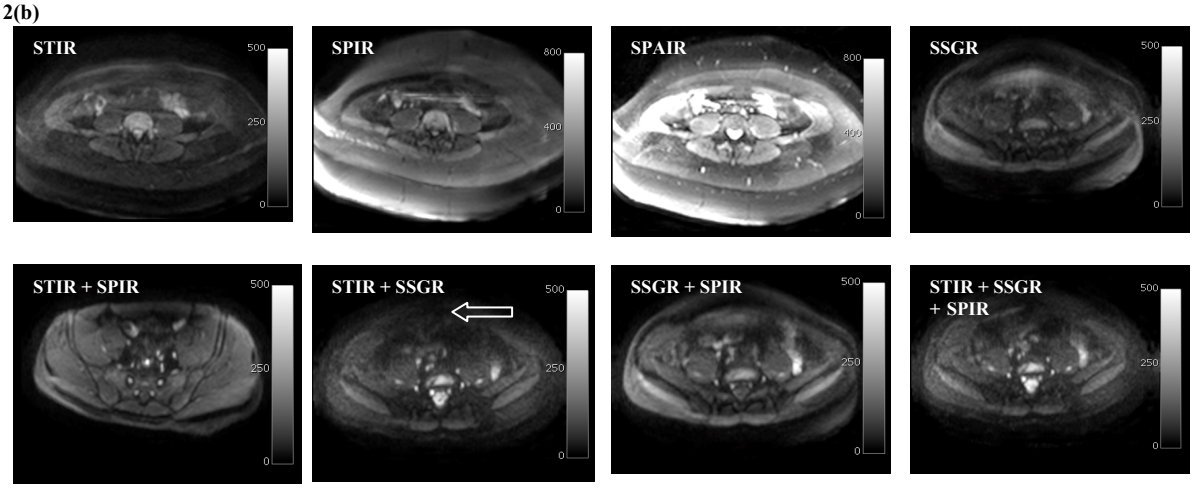


Figure 2(b)



2(a) An example b = 0 s mm^{-2} image acquired using combined STIR and SPIR fat suppression showing ROIs drawn around the Psoas muscle (green) and around the perimeter of the body, not including fat signal (red). **2(b)** Example b = 800 s mm^{-2} images of each of the tested fat suppression combinations. Note the loss of water signal in some of the images acquired using SSGR as demonstrated by the **white arrow**. Note that due to time restrictions not all fat suppression techniques could be tested on the same volunteer.