Automated Fat-Water Identification in Phase Sensitive SSFP

A. Mazumdar[1], B. Hargreaves[2], E. Han[1], A. Brau[1], H. Yu[3], J. Brittain[1]

[1]Applied Sciences Lab - West, GE Healthcare, Menlo Park, CA, United States, [2]Department of Electrical Engineering, Stanford University, Stanford, CA, United States, [3]Department of Radiology, Stanford University Medical Center, Stanford, CA, United States

Introduction

Balanced SSFP has become an increasingly popular technique in magnetic resonance imaging (MRI). A variety of SSFP imaging methods have been introduced for separating water and lipids [1-5]. The majority of these approaches require at least twice the scan time of standard SSFP. Hargreaves, *et al.* [5] presented a phase sensitive approach (PS-SSFP) that requires no additional time compared to standard SSFP.

While phase sensitive SSFP accurately separates chemical species, no automated method exists to consistently *identify* resulting fat and water images for annotation purposes. Similar problems arise with separation of white and gray matter in phase sensitive IR[6]. In PS-SSFP, each pixel in the image is rotated by a fitted phase onto the real axis in the complex plane. Due to phase ambiguity, it can be unclear whether positive real values represent fat or water after rotation. In this work, we present an algorithm that consistently and accurately identifies fat and water in PS-SSFP musculoskeletal images.

Methods

A 3D balanced SSFP sequence was implemented on a 1.5T Twinspeed Excite platform (GE Healthcare, Milwaukee, WI). Following informed consent, three scans of healthy knees were imaged using a SSFP sequence and a quadrature knee coil. After source images were reconstructed, the 3D images were processed using the PS-SSFP fat-water separation algorithm. All Fourier image reconstruction was performed on-line, and subsequent fat-water separation was performed using an on-line region-growing phase correction scheme [5].

In SSFP, the signal intensity of fat is considerably higher than that of other tissue due to its high T2/T1 ratio. This observation is leveraged to determine whether positive signals represent fat or water. For each slice in an image, pixels are grouped into those with positive real parts and those with negative real parts. The average magnitude for each group is calculated, and the group with the higher average is assumed to represent fat.

This calculation is repeated for each slice across the imaged volume. The ratio of the magnitude of the average positive signal to the magnitude of the average negative signal is compared for each slice. Since PS-SSFP consistently separates fat and water, it is only necessary to identify fat and water correctly on one particular slice in the 3D image. This identification can then be applied across all slices. Therefore, the slice with the greatest difference between positive and negative averages can be considered when identifying fat and water.

Results

An example of the PS-SSFP separation is shown in Figures 1 and 2. Sagittal images of the knee were acquired with the following parameters: TR=5.7ms, TE=2.9ms, Bandwidth=±62.5kHz, Slice Thickness=1.0mm, FOV=15x15, Flip Angle=23°. It is apparent that the magnitude of the average intensity of Figure 1 is greater than the magnitude of the average intensity of Figure 2. For this particular slice, the magnitude of average intensity of Figure 1 is 519, while the magnitude of average intensity of Figure 2 is 194. The ratio of average positive to average negative is 2.67. From this ratio, we are able to accurately identify Figure 1 as the fat image, and Figure 2 as the water image. This indicates that all positive pixel values in this 3D image can be classified as fat.

Figure 1   Figure 2

The ratio of the average positive signal to average negative signal for the three knee scans is shown across slices of the 3D volumes (Figures 3,4,5). In each of the three scans, the peak ratio between the intensity of fat and water is greater than two. This indicates that the average intensity of the fat image is double the average intensity of the water image. As shown in Figs. 3, 4, and 5, the center slices tend to have more pronounced differences between average signal intensities than edge slices.

Discussion

We have presented a method that accurately identifies which image represents fat and which represents water after PS-SSFP reconstruction. While synovial fluid also appears bright in SSFP musculoskeletal images due to its high T2/T1 ratio, it typically represents only a small fraction of the pixels in the water image and therefore we expect it will not contribute significantly to the average calculated pixel value.
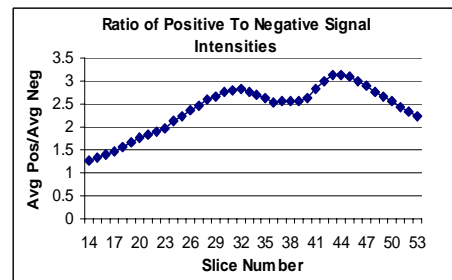

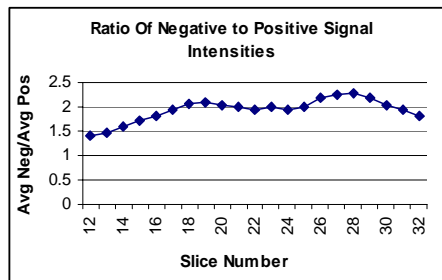**Figure 3** : Knee scan with parameters(TR:5.7ms, TE:2.9ms, Bandwidth:62.5kHz, FOV:15x15, Slice Thickness:1.0mm, NEX:3)

Figure 4 : Knee scan with parameters(TR:5.6ms, TE:2.8ms, Bandwidth:41.7kHz, FOV:12x12, Slice Thickness:1.5mm, NEX:4)
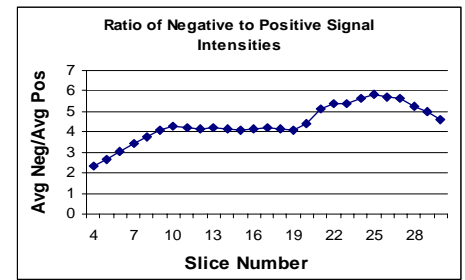

Figure 5 : Knee scan with parameters(TR:4.5ms, TE:2.2ms, Bandwidth:41.7kHz, FOV:13x13, Slice Thickness:1.0mm, NEX:2)

References: 1. Vasanawala, MRM 1999, 42:876-883; **2.** Hardy, Proc ISMRM 2002, p473; **3.** Vasanawala, MRM 2000, 43:82-90; **4.** Reeder, AJR 2003, 182:357-362; **5.** Hargreaves, MRM 2003, 50:210-213; **6.** Xiang, JMRI Sept-Oct 1996, 5:775-82.