Robust Multicoil Reconstruction for Phase-Sensitive Fat-Water Separation

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Introduction: Phase-sensitive (PS) SSFP [1,2] is an efficient fat/water separation method, successfully used in several applications including angiography [1], musculoskeletal [3] and abdominal [4] imaging. It generates and detects a $180^\circ$ phase-difference between fat and water. In previous work, water images reconstructed from individual coils with PS-SSFP were combined [4,5]. However, abrupt spatial phase-variations from surface-coil arrays can lead to fat-water misclassification. In this work, we propose a simple and robust multicoil PS-SSFP reconstruction. First, individual coil images are combined to yield an image with reliable phase. Fat and water are then successfully separated using this combination.

Methods: If TR = 4.6 ms at 1.5 T, the water and fat resonances are at the centers of adjacent balanced (b)SSFP pass-bands with a $180^\circ$ phase-difference. The resulting signal is $S = (W-F)P$, where W and F denote the water and fat signals, and P represents spatial phase-variations. In regular PS-SSFP, the coils are processed independently [5]. First, smooth spatial phase-variations are removed from S with a region-growing phase-correction [2,6]. The sign of (W-F) is then used to separate the two resonances. However, abrupt phase variations at the edges of surface coils can lead to partial fat-water misclassifications within individual images, which may not be correctable by a global sign change [5] (Fig. 1).

In fact, for each spatial location, at least one coil provides accurate phase information. We propose to obtain an improved estimate for the sign of (W-F): $\theta_c = \text{arg}(\sum_i |S'_i|)$, where $S'_i$ is the phase-corrected image from the $i^{th}$ coil. This combination weighs the coils based on their magnitude to yield a minimum-variance estimate and is relatively immune to inter-coil phase cancellations [7]. Each voxel is classified as W or F based on $\theta_c$, and the magnitude image is then formed with a sum-of-squares combination.

Results: 3D dual-acquisition phase-cycled bSSFP [2] images of the lower leg were acquired on a 1.5 T scanner with an 8-channel array: $\alpha=90^\circ$, 32 cm FOV, 1.73 mm$^3$ voxel size, TR/TE = 5/2.5 ms. Reconstructions from bSSFP, independent-coil PS-SSFP with global sign change, and the proposed method are displayed in Figs. 1-3. Independent-coil PS-SSFP fails in regions of abrupt phase changes. In contrast, the proposed method accurately estimates the phase and achieves reliable fat-water separation.

References: