Region-Growing Reconstruction for Large-Angle Multiple-Acquisition bSSFP

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INTRODUCTION: Balanced steady-state free precession (bSSFP) is a rapid and SNR-efficient imaging method, but suffers from characteristic bands of signal loss in regions of large field inhomogeneity. Several methods have been developed to eliminate or reduce the severity of these banding artifacts, typically involving the acquisition of multiple bSSFP data sets (and the accompanying increase in scan time) [1-4]. Fat suppression with bSSFP is also challenging; most existing methods require an additional increase in scan time, and some are incompatible with bSSFP band-reduction techniques [5-7].

A novel method for simultaneously suppressing fat and reducing bSSFP banding artifacts in the presence of field inhomogeneity was recently presented, called large-angle multiple-acquisition (LAMA) bSSFP [8]. The new technique was motivated by the need for such a sequence when using bSSFP for flow-independent peripheral angiography. LAMA bSSFP as described in [8] requires the acquisition of a field map, although the paper suggests that intelligent post-processing of the two phase-cycled bSSFP acquisitions could eliminate the need for separate field map acquisition.

In this work, we present a new region-growing reconstruction technique for LAMA bSSFP that eliminates the need for field map acquisition.

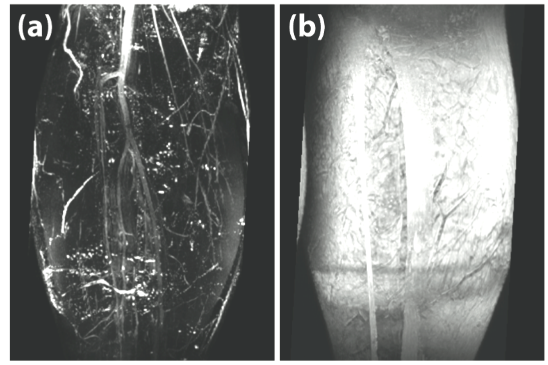

Figure 1: Maximum intensity projection images of the 3D bSSFP dataset of the lower leg of a normal volunteer with (a) new region-growing algorithm and LAMA bSSFP reconstruction (eliminating the need for field map acquisition), and (b) standard root sum-of-squares reconstruction without fat suppression. The region growing technique with LAMA bSSFP effectively suppresses fat while eliminating banding.

THEORY AND METHODS: The LAMA bSSFP technique relies on the fact that bSSFP signal level as a function off-resonance frequency is approximately sinusoidal for many tissues at large flip angles (~70° or greater). Acquisition of two large-flip-angle bSSFP images with RF phase increment $\Delta\phi = 0°$ and $\Delta\phi = 180°$ yields images with spectral profiles approximating a sine and a cosine, respectively. An image with spectral profile shifted by an arbitrary Δf can then be synthesized from the two acquisitions, using the relationship $\sin(f + \Delta f) = \cos(\Delta f)\sin(f) + \sin(\Delta f)\cos(f)$. Appropriate choice of TR and Δf for each voxel allows fat to be shifted to a null in the spectral profile while water is in a passband on a voxel-by-voxel basis, simultaneously suppressing fat and eliminating SSFP banding.

The required frequency shift Δf for a given voxel can be determined through acquisition of a field map, but this requires extra time. Our region-growing reconstruction technique seeks to determine Δf for a given voxel by reconstructing the voxel across a range of Δf values and then identifying the Δf value that yields either minimum signal (for a voxel identified as predominantly fat) or maximum signal (for a voxel identified as predominantly water). We start the analysis in a known fat voxel, and identify the Δf value yielding minimum signal for that voxel. We then do the same for adjacent voxels. If the difference in Δf values of adjacent voxels is large and corresponds roughly to the relative frequency difference between fat and water resonances, the algorithm determines that we have crossed a fat/water boundary, and the new voxel is categorized as either fat or water accordingly. The algorithm progresses as described, eventually classifying each voxel within the sample as either predominantly fat or predominantly water, and determining each voxel's Δf value.

Two 3D phase-cycled bSSFP datasets were acquired of the lower leg of a normal volunteer on a Siemens 3T scanner. Parameters for the bSSFP acquisitions were: TR/TE = 5.7/2.85 ms, FOV = 25.6x12.8x12.8 cm, matrix size = 256x128x128, flip angle = 70 degrees, total acquisition time = 3 min 23 sec. Our region-growing LAMA reconstructions technique was then performed to form a fat-suppressed image of the 3D volume. A root sum-of-squares reconstruction (no fat suppression) was also performed for comparison.

RESULTS AND DISCUSSION: A maximum intensity projection (MIP) image of the 3D dataset after fat-suppression with our new region-growing reconstruction and LAMA bSSFP is shown in Figure 1(a). A MIP of the standard root sum-of-squares reconstruction (no fat suppression) is shown in Figure 1(b) for comparison. Our new region-growing reconstruction technique performs quite well, effectively eliminating banding artifact and accurately suppressing much of the fat. While further work is needed to gauge the robustness of the new technique across a range of conditions and applications, these initial results suggest that acquisition of a field map is not strictly necessary for use of LAMA bSSFP.

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