Iterative reconstruction for off-resonance effects in SWIFT imaging

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Introduction: Strong local field inhomogeneities are challenging for MRI. The challenges are 3 fold: excite the larger bandwidth, acquire the signal from regions with short T2*, and determine the correct and undistorted spatial frequency of the signal. The excitation and acquisition of fast relaxing signals are well captured by the SWIFT [2] sequence. Even with high bandwidth, as used for SWIFT, the acquired signal can still be spatially distorted. Traditional methods, such a two acquisitions with different TE's, for estimating field maps, are not always possible options. This is a concern for long acquisitions that can not be repeated, in-vivo imaging of moving organs (heart, lungs etc.), or when imaging short T2 signals, where the signal is dephased even at the shortest possible TE. For correction of field inhomogenieties when mapping is not possible auto-focusing methods [3] have been proposed and used for smoothly varying field inhomogenieties. For 3D radial imaging the feasibility of quickly reconstructing the acquired signal to a different off-resonance frequency by applying radial phase shifts in the gridded k-space makes it tractable to use iterative methods. To demonstrate that signal recovery is feasible of the more complex SWIFT signals, we implemented an iterative frequency shift method similar to that described in [4] for correction of the unknown local magnetic fields which are not necessarily slowly varying.

Methods: Murine embryonic stem cells were labeled with Feridex (5.2±0.7 pg iron per cell) and 2 millions of such labeled cells were grafted directly into the myocardium of a rat. The heart was harvested and perfused with 4% formalin and suspended in Fomblin oil (NJ). Imaging was performed on a Varian 9.4T scanner, flip angle 22 deg, TR=2ms, TE=6μs, 96000 spokes, with NEX=4. Acquisition time was ~15 min., and with a resolution of 98 μm^3.

After reconstruction (through gridding) to a Cartesian grid of the standard SWIFT signal [2] a 3D ROI covering the insertion area of the SPIO's was selected for auto-focusing. The VOI selected encompassed 100x60x50 voxels. A series of images with different off-resonance shift are used as basis for estimating the correct reallocation of signal. A minimization function for minimizing the square root of the magnitude of the imaginary part of the signal was used, similarly to [4]. For sequential refinement, decreasingly smaller VOI's of 13^3, 9^3, 7^3, 5^3, 3^3 voxels were used for averaging to prevent noise amplification.

Results: Imaging with SWIFT confirms a locally and moderately strong T2*. In figure 1 (left) the location of the ROI in a slice is identified. The top row shows hyperintense signal due to T2* at the border of the SPIO injection site for sequential slices. After correction, more homogenous signal distribution of the voids observed in the SWIFT acquisition is achieved (figure 1 bottom row). The residual bright signal is not inconsistent with bright contrast from SPIO's when imaged with SWIFT.

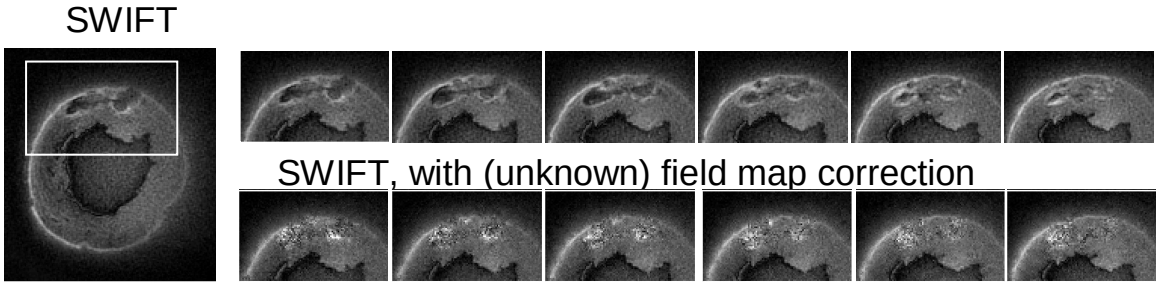

Fig 1. Left image is a cropped FOV of representative short axis images of in-vitro rat heart. The box indicates the size of the VOI used for off-resonance correction. Top row, standard SWIFT for 6 sequetial slices, with some ballooning due to T2*. Bottom row, reconstruction of signal after iterative off-resonance correction.

References: [1], Garwood, JMR(153) 2001, [2] Idiyatullin, JMR(181) 2006, [3], Noll MRM(25) 1992, [4] Man, MRM (37) 1997

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