In vivo SWIFT Imaging of SPIO Labeled Stem Cells Grafted in the Heart

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Introduction The SWIFT (SWeep Imaging with Fourier Transformation) technique (1) was introduced to image spins with extremely fast transverse relaxation rate. SWIFT features extremely short acquisition delay and thus can substantially reduce T2*-induced signal voids that normally occur in gradient-echo (GRE) detection of superparamagnetic iron-oxide (SPIO) particles. We previously injected SPIO-labeled cells into the heart and performed *ex-vivo* SWIFT imaging. Because SWIFT retained signals from the short T2* spins and these off-resonance signals "piled-up" in the images, the approximate locations of SPIO particles could be directly visualized with high (positive) contrast-to-background ratios. The conspicuity of the SPIOs is the greatest in the imaginary component of the image data, where on-resonance signals were not visible. These features were found to facilitate the detection of stem cells in the tissue. Here we present the first *in-vivo* SWIFT cardiac imaging of SPIO-labeled stem cells grafted in the heart.

Methods Murine embryonic stem cells (5 million) labeled with Feridex were injected directly into the myocardium of athymic rats. ECG-gated, 3D-SWIFT and 2D-GRE imaging were performed sequentially on a 9.4T magnet (Varian Direct Drive) while the animal was maintained under gas anesthesia and prone on a surface coil (ID= 4.8 cm) placed under the chest. For 3D SWIFT sequence: RF excitation (flip angle =10°) using a hyperbolic secant pulse (2) with an excitation bandwidth (sw) of 125 kHz was applied over a tissue slab fit inside a 7x7x14 cm^3 FOV; 32000 spokes (including positive and negative readout gradients) were acquired in k-space with 128 post correlation complex points in each radial fid; TR=2.5ms, acquisition delay= 6 µs, and 4 spokes were acquired after each R-wave trigger with one signal average leading to a total acquisition time of 27.5 min. Parameters for multi-slice GRE sequence include TR= 6 ms, flip angle= 30°, TE=3.3 ms, 0.3 mm thick slices, sw=50 kHz, 128 x 128 matrix in 7x7 cm^2 FOV and 12 averages.

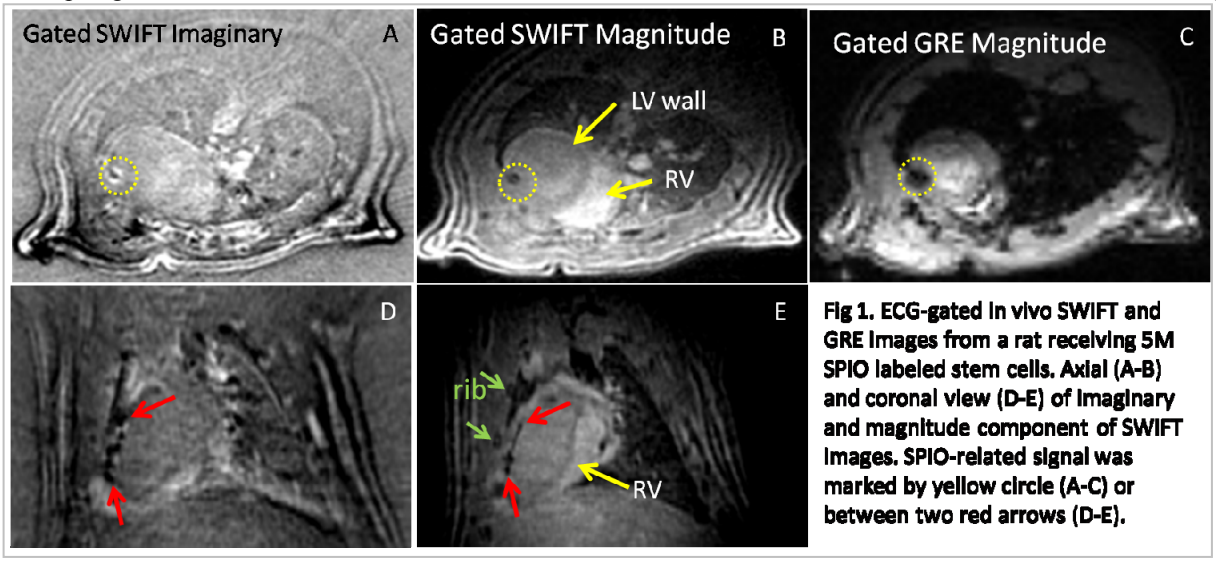

Fig 1. ECG-gated In vivo SWIFT and GRE Images from a rat receiving 5M SPIO labeled stem cells. Axial (A-B) and coronal view (D-E) of Imaginary and magnitude component of SWIFT Images. SPIO-related signal was marked by yellow circle (A-C) or between two red arrows (D-E).

Results ECG-gated SWIFT magnitude images at end-diastolic phase show superior SNR and contrast (B, E). Myocardial wall, LV and RV lumen, major vessels in the chest and lung parenchyma are well delineated. SPIO-containing cells were visualized as a hypointense region (circle in B), which appears more focused compared to the hypointense region on GRE image (C). Correspondingly, in the imaginary images (A), the signals related to SPIO-labeled cells are intense and shifted to form a bright rim (positive) surrounding a hypointense center (negative). Both positive and negative SWIFT imaginary signal originates from off-resonance spins (frequency shifted by the presence of SPIO-labeled cells). The coronal view clearly shows the distribution of SPIO-labeled cells along the anterior myocardial wall (red arrows, E) along with the mingled positive and negative contrast spots on the imaginary image (D). Tissue boundaries also induce frequency shifts therefore present signals on the imaginary image. However, since the magnitude and imaginary images are perfectly registered (generated from the same data set), the SPIO spot can be easily separated from other off-resonance spins by reading both images. In addition, the myocardium wall appears homogenous in SWIFT comparing with GRE leading to less ambiguity in detection of SPIO-labeled cells.

Discussion These results represent the first *in-vivo* SWIFT cardiac images. Off-resoance signals associated with SPIO appear enhanced on SWIFT imaginary images and can be readily registered on the magnitude images, which clearly revealed myocardial anatomy; thus, acquisition of a separate reference image was not required. These data suggest that SWIFT might be an alternative to currently available positive contrast methods (3-6), attractive especially in cardiovascular applications.

References

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