Positive Contrast Fe Nano-particle Imaging of Mouse Brain Vasculature with SWIFT

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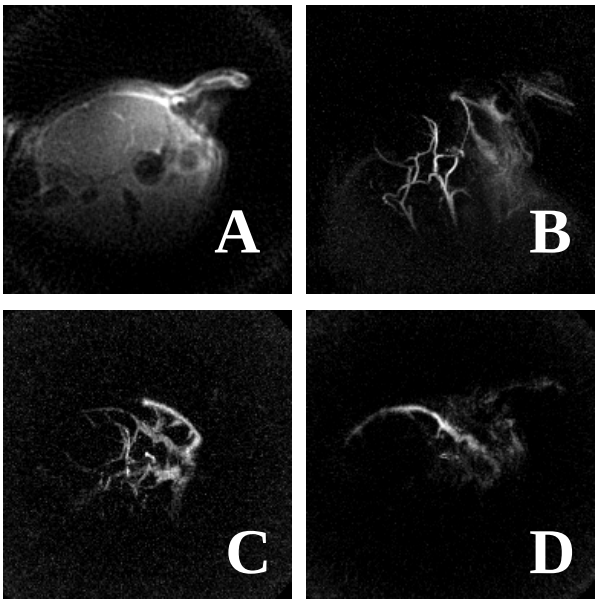
Introduction: We demonstrate initial results with positive contrast enhancement in an *in-vivo* wild type mouse brain, after bolus I.V. injection(s) of the mono-crystalline ion oxide nano-particle solution[1] MION-47. MION-47 has both R_1 and R_2* relaxivity, but the R_2* relaxivity typically dominates at high concentrations and/or high fields[2]. Utilizing SWIFT[3] (SWeep Imaging with Fourier Transform) we show high field, high concentration R_1 induced positive T_1 contrast at 5mg/kg and 20 mg/kg MION-47 doses.

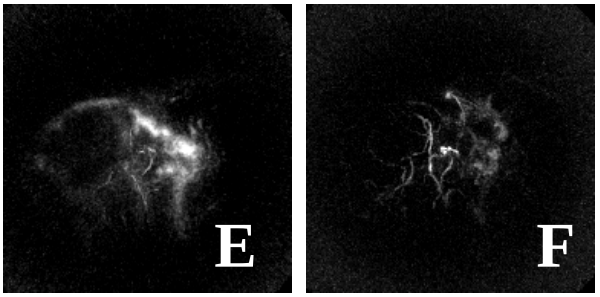
SWIFT is a novel radial imaging sequence utilizing gapped frequency-swept pulse excitation and nearly simultaneous signal acquisition in the time between the gaps[4]. SWIFT utilizes the correlation method[5] which removes phase differences due to the time of excitation and produces FID data as if the spins were simultaneously excited by a short duration pulse. SWIFT has an intrinsically short dead-time, at present hardware-limited to ~5-15μs. This provides sensitivity to very fast relaxing spins (short T_2 or T_2*) similar to UTE (Ultra-short TE) sequences[6].

Methods: A wild type mouse (20g) was anesthetized with 2% Isoflurane, catheterized with pre loaded line of 10:1 dilution of MION-47 and placed in our 9.4 T 31 cm bore animal magnet (Varian/Magnex). The animal was placed in a custom built heated holder and quadrature surface coil with two ~1 cm loops 2 mm from the top of the head. A syringe reservoir of 0.5 cc diluted MION-47 terminated the I.V. line. A pre-injection series of SWIFT images were acquired during the first 20 minutes and then MION solution was injected slowly by hand to 5mg/kg dose (100 μL). After approximately 10 min a post contrast series of SWIFT images were taken lasting approximately 30 min, and then another 300 μL bolus of MION dilution was injected for a total dose of 20 mg/kg. Post second bolus imaging was acquired during the final 30 minutes.



Results and Discussion: Here we present a series of images summarizing the results. In all image datasets the bandwidth (for excitation of base-band and acquisition) was 62.5 kHz. Each 3d radial SWIFT dataset consists of 32,000 unique FID views (spokes). Duty cycle of used for excitation Hyperbolic Secant pulse was 25%. TR was 6.1 ms with 4.1 ms of acquisition time included. The diameter of the FOV was 3cm.. Total time for each image was 3.5 min including steady state scans. Processing of the SWIFT data was accomplished by correlation with the RF shape file, and data driven RF distortion correction[7]. The radial reconstruction was accomplished by gridding with 1.25x over-sampled width 2.5 Kaiser-Bessel kernel and $1/r^2$ density weighting[8].

Figure A shows a representative slice from the pre-MION 11° flip dataset. In all images the mouse is in the same position, slightly rotated transverse. Figure B shows a maximum intensity projection (MIP) of the pre-MION 45° flip dataset. Inflow contrast is seen in the large arteries. Figure C shows a subtraction, and the MIP of the 11° flip, 5mg/kg MION – Pre-MION datasets. Enhancement in seen in the largest veins and is not likely to be a result of inflow (due to being veinous and the image being a subtraction). In Figure D, 45° flip, 5mg/kg MION – Pre-MION MIP enhancement is seen in the medium and large veins, and some arteries.



After the second bolus, in Figure E, 45° flip, 20mg/kg MION – Pre-MION MIP, contrast can be seen throughout the vascular system, and blooming but no signal loss in large veins. This is a desirable property resulting from SWIFT's short dead-time, and allows T_1 enhanced ROIs to be quantified without confounding T_2* de-phasing. Finally in Figure F a different enhancement pattern, with less blooming can be obtained by subtraction the two post injection datasets, i.e. 20mg/kg MION – 5mg/kg MION MIP.

In closing we have demonstrated positive T_1 contrast with Fe nanoparticles in a wild type mouse brain, *in-vivo*. This is simple T_1 contrast, without resorting to various off resonance methods[9] or preparation. We look forward to further investigation and exploration of quantitative performance of the novel contrast combination of MION and SWIFT.

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References

1. Shen, T., Weissleder, R., Papisov, M., Bogdanov, A. & Brady, T. J. Monocrystalline iron oxide nanocompounds (MION): physicochemical properties. Magn Reson Med 29, 599--604 (1993).
2. Wu, E. X., Wong, K. K., Andrassy, M. & Tang, H. High-resolution in vivo CBV mapping with MRI in wild-type mice. Magn Reson Med 49, 765-70 (2003).
3. Idiyatullin, D., Corum, C., Park, J.-Y. & Garwood, M. Fast and Quiet MRI Using a Swept Radiofrequency. Journal of Magnetic Resonance (2006).
4. Idiyatullin, D., Corum, C. A., Moeller, S. & Garwood, M. in Manuscript In Preparation (2007).
5. Dadok, J. & Sprecher, R. F. Correlation NNW spectroscopy. Journal of Magnetic Resonance (1969) 13, 243--248 (1974).
6. Robson, M. D., Gatehouse, P. D., Bydder, M. & Bydder, G. M. Magnetic resonance: an introduction to ultrashort TE (UTE) imaging. J Comput Assist Tomogr 27, 825-46 (2003).
7. Moeller, S., Corum, C. A., Idiyatullin, D., Chamberlin, R. & Garwood, M. in Manuscript in Preparation (2007).
8. Beatty, P. J., Nishimura, D. G. & Pauly, J. M. Rapid gridding reconstruction with a minimal oversampling ratio. Medical Imaging, IEEE Transactions on 24, 799 - 808 (2005).
9. Conolly, S. M. et al. in 46th {ENC} {C}onference (2005).