Calcification Imaging with SWIFT in Rat Brain

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INTRODUCTION Phase imaging or susceptibility weighted imaging (SWI) is usually conducted with gradient echo (GE) sequences to study many different pathologies [1]. The problem of phase imaging is the removal of the phase contributions created by bulk magnetic field inhomogeneities, sequence dependent timing and gradient errors, and phase unwrapping. This is usually done by high-pass filtering or by using more complicated algorithms that can be time consuming [2]. SWIFT (sweep imaging with Fourier transformation) is a recently introduced [3] virtually zero acquisition delay pulse sequence using gapped hyperbolic secant pulses. Interestingly, even though there is no time for phase accrual at the top of the post correlation FID, phase behavior is still seen in the imaginary or phase component of the reconstructed image due to off resonance phase accrual during acquisition [4]. In comparison to GE phase imaging, there is no need for post-processing since the sequence dependent (as opposed to object dependent) phase effects are minimal. To test the abilities of SWIFT phase imaging, it was applied to detect calcifications induced by brain injury. Calcifications themselves do not have hydrogen, but do affect nearby spins. The inherent diamagnetism of the calcification can be used to distinguish them from features with positive susceptibility such as veins and air bubbles in *ex vivo* imaging using the sign change of the dipole.

MATERIALS AND METHODS Two rat animal models causing brain injury and calcifications in chronic phase were used: systemic pilocarpine injection inducing status epilepticus (n=5) and lateral fluid percussion traumatic brain injury (TBI, n=5). Epileptic animals were sacrificed at 6 months and imaged *ex vivo*, TBI animals were imaged *in vivo*, sacrificed at 5 months and imaged *ex vivo*. *Ex vivo* and *in vivo* Imaging was conducted at 9.4 T vertical and horizontal magnets with Varian Direct Drive consoles using 19 mm quadrature volume and quadrature half volume coils, respectively. SWIFT parameters for *ex vivo* imaging were TR = 5 ms, sw = 62.5 kHz, α = 5º, and for *in vivo* imaging TR = 8.2 ms, sw = 31.125 kHz and α = 5º. Matrix size for all images was 256^3. The calcifications were located and identified by using the imaginary and phase parts of the SWIFT images. The volumes of the calcifications were estimated from the magnitude images and correlated with Nissl and Alizarin (calcium) stained sections.

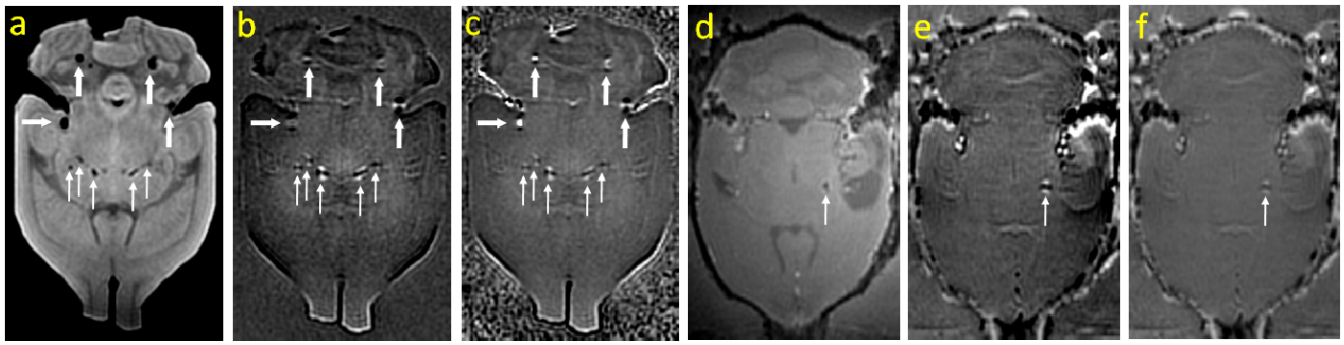

Fig 1. (a) Magnitude, (b) imaginary and (c) phase SWIFT images of an *ex vivo* pilocarpine rat brain. *In vivo* (d) magnitude, (e) imaginary and (f) phase SWIFT images of a TBI rat brain. Thin arrows point calcifications, thick arrows air bubbles.

RESULTS All animals showed calcifications. Figure 1.a,b,c) shows a representative case of a *ex vivo* pilocarpine rat brain and d,e,f) an *in vivo* TBI brain with calcifications. Figure 2. shows correlation of the *ex vivo* calcification size of between MRI and histology with calcifications pooled from all animals (r = 0.84). Total of 44 calcifications in the pilocarpine brains were detected with SWIFT. In TBI animals, *ex vivo* imaging revealed one calcification per animal, *in vivo* imaging one in three animals. Additionally, very small calcifications missed by MRI were seen in histology. The smallest detected *ex vivo* calcification was measured to be 0.0037 mm^3 in histology and 0.0151 mm^3 in MRI. Calcification sizes measured *in vivo* were 0.16, 0.20 and 0.22 mm^3 in comparison to histology 0.07, 0.05 and 0.17 mm^3, respectively.

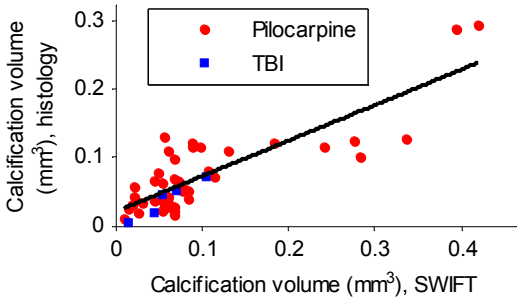

Fig 2. Correlation of the calcification volume between histology and *ex vivo* magnitude images (r = 0.84).

DISCUSSION AND CONCLUSION We were able to show that SWIFT can detect and differentiate calcifications based on their dipole like fields without post-processing of the phase images. Compared to GE methods, SWIFT is likely to excel near high susceptibility differences due to its extremely short acquisition delay and broad excitation bandwidth.

A good correlation between size of calcification measured with MRI and histology was achieved. Differences can be explained by partial voluming, calcifications having a sub-voxel volume and that typical calcifications are not well defined units but are instead spread in the tissue. This also complicates the histological volume estimation and comparison to MRI, since histological detection limit is in the microscopic scale meaning that even the smallest particles could be separated.

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