Comparison of Conventional and Phase Enhanced T2* Weighted Gradient Echo Imaging for the Detection of Iron-Oxide Nanoparticles at Low Nano-Molar Concentrations

R. T. Seethamraju[1], K. Kwong[2], and D. Sosnovik[2]

[1]MR R and D, Siemens Medical Solutions, Charlestown, MA, United States, [2]Athinoula A. Martinos Center for Biomedical Imaging, Charlestown, MA, United States

Background and Aims:

Iron oxide nano-particles are playing an increasingly important role in molecular imaging. Several magnitude-based strategies have been used to image these nano-particles including T2, T2*, T1 and off-resonance techniques. Recently, however, a phase enhanced gradient echo approach termed susceptibility weighted imaging (SWI) [1] has been developed to detect deoxyhemoglobin with high sensitivity. The aim of our study was therefore to characterize the sensitivity of phase enhanced gradient echo imaging for the detection of nano-molar concentrations of iron oxide and compare this technique to a conventional T2* based gradient echo approach.

Materials and Methods:

Nano-molar solutions of MION-47 (Center for Molecular Imaging Research, Boston MA) were placed in 10 mm NMR tubes and suspended in a water bath. The tubes contained solutions of 10 nmol/l, 30, nmol/l, 100 nmol/l, 200 nmol/l, 400 nmol/l and 600 nmol/l. The MION phantom was imaged on a 1.5T scanner (Avanto, Siemens AG, Erlangen) using a commercial head coil and prototype versions of a multi-echo gradient echo (mGRE) sequence and a susceptibility weighted imaging (SWI) sequence. The mGRE sequence consisted of 12 echoes, ranging from 4.75-57 ms, in a mono-polar readout. Other parameters included: TR=3150ms, Slice thickness =3mm, FOV=158x180mm, 224x256 matrix (0.7x0.7mm pixel spacing). The SWI sequence consisted of a 3D acquisition with images acquired at 9 echo times ranging from 40-72 ms. Other parameters included: TR=81ms, Slice thickness =3mm (interpolated), FOV=180x180mm, 273x384 matrix (0.5x0.5mm pixel spacing). A phase mask value of 4 was used at which no aliasing of the phase was seen.

Results:

Significant differences were seen on T2* weighted images in the signal intensity between the low and high concentrations of MION (Figure 1). The tubes are shown in increasing concentration counter clockwise starting at 10 nmol/l at the white arrow. Only subtle differences in signal intensity were seen on the T2* weighted images between the 10 and 30 nmol/l MION solutions. The construction of T2* maps (Figure 2) showed these differences more clearly. Signal differences on the phase-enhanced gradient echo images were also subtle at low MION concentrations and, as in the case of conventional GRE imaging, R2* maps were needed to see these differences more clearly (Figures 1, 2). A strong linear dependence of R2* on MION concentration was seen (Figure 3) for both methods with a high degree of correlation. However, when signal intensity as a function of MION concentration was evaluated at only a single echo time, differences in the two techniques were seen. A more gradual loss of signal intensity with SWI was seen at lower MION concentrations at a TE of 57 ms, while a more rapid loss was seen at higher concentrations (Figure 4).

Conclusion:

MION concentrations in the low nano-molar range could be detected by both methods. In addition a high degree correlation was seen between R2* values obtained with the 2 measurements although it is possible that differences in signal behavior over a finite range of echo times may exist between the two techniques. The relative sensitivities of the two techniques as a function of MION concentration will thus require more study. However, advantages of the phase-enhanced SWI approach include the 3D nature of its acquisition and its shorter scan time. Although further study will be needed, SWI could become a useful adjunct to currently used techniques to image iron oxide in-vivo.

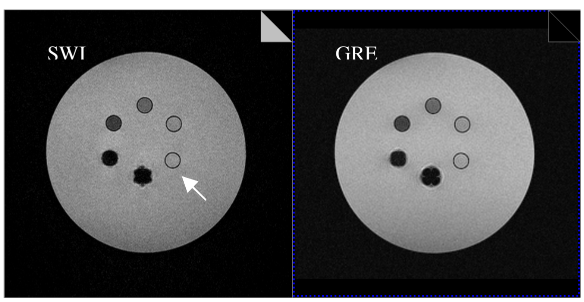

Fig 1. T2* weighted images (TE ~ 57 ms). SWI image on the left conventional GRE image on the right with arrow pointing to the lowest MION concentration.

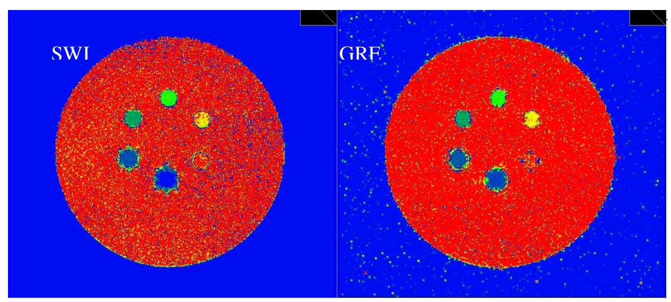

Fig 2. T2* maps SWI on the left and GRE on the right

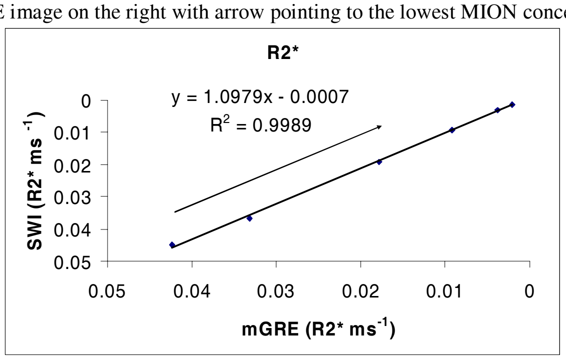

Fig 3. Correlation between R2* values for SWI and mGRE

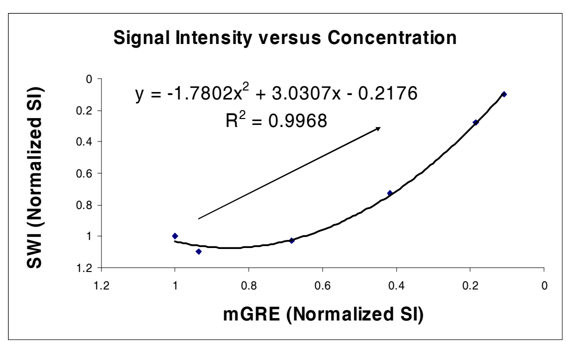

Fig 4. Correlation of signal intensity changes with MION concentration for SWI and mGRE. Signal intensities in both cases have been normalized to the value obtained at the lowest MION concentration. The TE for all images in the graph was approximately 57 ms.

The arrows in both the figures indicate the direction of the concentration

[1] Haacke EM, Xu Y, Cheng YC, Reichenbach JR, Susceptibility Weighted Imaging (SWI), Magn Reson Med. 2004 Sep; 52(3): p 612-8.