Noise Dependence of T2* Maps on Echo Times and Number of Echoes

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Aim: To optimize imaging strategies for T2* parametric mapping for Lymphotropic Nano-particle enhanced magnetic resonance imaging (LNMRI) and to establish a relationship between the number of echoes, the timing of echoes and the noise in the estimated T2* maps.

Background: T2* maps are an important quantitative parameter for detection of minimal nodal metastatic disease with lymphotrophic nano-particle enhanced MRI (LNMRI) (1, 2). These maps are particularly important in detection of metastases in small, unenlarged (occult) lymph nodes, however technical sequencing restrictions can limit the extent of detection. We have previously shown that maps obtained from a standard dual echo GRE sequence are inaccurate mathematically for computing T2* maps (3). On the other end of the spectrum, T2* maps computed from multiple echoes, though mathematically well conditioned, may not produce the best T2* maps especially due to the low signal to noise ratio (SNR) and increased susceptibility artifact inherent at longer TE values.. This is especially problematic in smaller metastatic lymph nodes (e.g. <4mm). We therefore aimed to optimize our parametric mapping strategy for quantifying T2* in a phantom model with varying concentrations of magnetic iron-oxide nano-particles.

Materials and Methods: A phantom (Fig 1) was created with Nano-molar solutions of MION-47 (Center for Molecular Imaging Research, Boston MA) 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 phantom was imaged on a 1.5T Siemens Avanto scanner and a 3T Trio Tim scanner using a mono-polar multi echo GRE (mGRE) sequence. The mGRE sequence parameters were: TR=3150ms, TEs = 4.76 to 57.2 ms, Slice thickness =3mm, FOV=158x180mm.
A maximum of twelve echoes were obtained for each slice and T2* maps were fit with a mono-polar exponential algorithm (Matlab) using 2 echoes and increasing monotonically to the maximum of 12 echoes. The signal to noise ratio (SNR) and contrast to noise (CNR) for each of the vials was calculated for all these maps at the addition of each echo time. The best map was chosen based on the best SNR and CNR of the maps. For CNR the surrounding water in the phantom was taken as the base.

Results: The SNR and CNR for a dual echo map (TE= 4.76 and 8ms), is extremely low, which validates our assumption that a dual echo T2* map is ill-conditioned. Furthermore, at all concentrations of Fe+, SNR and CNR peaked at echo times of 23ms (4 echo fits) at 3T. The SNR at the optimal point did not seem to vary linearly with concentration of Fe^+. There was a similar trend at 1.5T though at lower concentrations (10 and 30 nmol/l), without a significant drop in SNR with additional echoes, emphasizing the shorter T2* at 3T relative to 1.5T. The peak at 1.5T occurred at 33ms.
Conclusions: We have established that the best possible T2* maps are obtained when echoes beyond 23ms at 3T and 33ms at 1.5T are discarded. We have also established that the SNR and CNR at 3T is much better for T2* maps when compared to 1.5T.

Fig. 1 Phantom with vials of different concentrations of Fe^+.

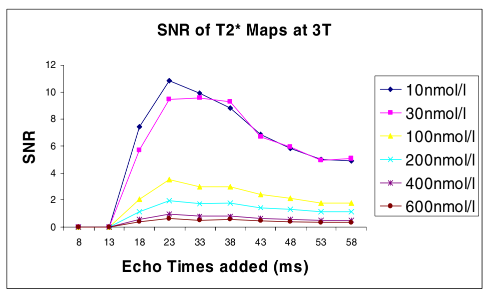

Fig. 2a Signal to noise ratio of computed T2*s as a function of added echoes for different concentrations of Fe^+.

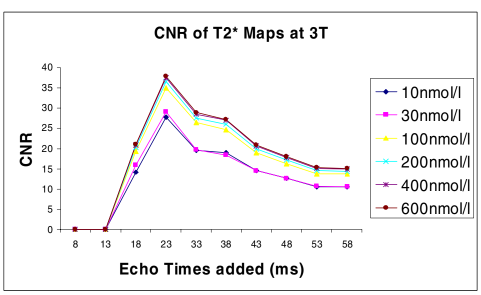

Fig. 2b Contrast to noise ratio of computed T2*s

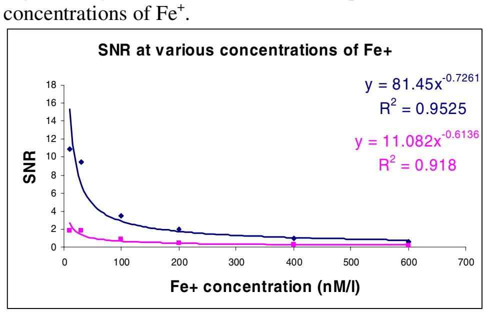

Fig. 2c SNR decay for various concentrations of Fe^+.

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