Reproducibility and SNR Optimization of Quantitative T2 Atherosclerotic Plaque Imaging with a Dual-Echo Technique

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Introduction:

T2 mapping of atherosclerotic plaques has the potential to provide accurate and reproducible information on plaque tissue composition, progression and response to treatment. T2 mapping technique has been applied in various circumstances for tissue characterization because it provides an objective means to assess tissue signal abnormalities [1, 2]. It has, however, been a challenge for T2 mapping of atherosclerotic patients to acquire time efficient data with high reproducibility. Dual-echo fast spin echo sequence is an attractive technique for T2 quantification because it is time-efficient and offers inherent registration of images with different echo times. Yet there have been few attempts to incorporate T2 mapping in atherosclerosis imaging [3]. To fill this gap, this study proposes a method to optimize the dual-echo protocol to improve T2-measurement reliability and reproducibility. Both phantom and human plaque data were used to evaluate the optimization process.

Theory:

The goal of this optimization process is to implement a higher SNR, which will improve the reproducibility of tissue characterization. The T2 time is assumed to be calculated by a two-point technique according to Eq.1 [3], and is referred to as T_{2eff}. SNR of T2 map is defined as the ratio between average signal intensity and corresponding signal standard deviation. By applying error propagation theory [4, 5], SNR of the T2 map could be expressed as (Eq.2),

$$T_{2eff} = \Delta \Big/ \ln\left(\frac{I_{pd}}{I_{T2}}\right) \qquad (1)$$

$$SNR_{t2map} = \frac{I_{T2eff}}{\sigma_{t2map}} = \frac{\frac{\Delta}{T_{2eff}}}{\sqrt{e^{\frac{2\Delta}{T2eff}}+1}} SNR_{pd} \qquad (2)$$

Where, σ is the standard deviation of T2 map; Δ is the echo spacing, i.e. the echo time difference between PD and T2 images. From the Eq.2, the SNR of T2map is related to echo spacing Δ, T_{2eff} time and image quality of PD-weighted image. We will focus on the optimization of echo spacing for specific T2 values that are most often seen in atherosclerosis imaging. As the majority of tissue components of the plaque have T2 ranges 25-70 ms at 1.5T [6], numerical simulation shows that an echo spacing of 40-50 will maximize the T2 map SNR (Fig. 1).

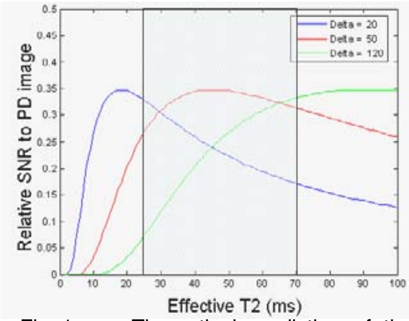

Fig. 1 Theoretical prediction of the optimized echo spacing, which indicates in the shaded area, Δ =50ms is more desirable

Methods and Material:

Phantom study 0.3mM solution of $MnCl_2$ and Gadolinium solutions (prepared from commercial contrast agent, Omniscan, NJ) at 0.2mM and 1mM concentration were scanned with dual echo SE and FSE protocols. Actual T2 of each phantom was measured by a series of single echo spin echo sequences, as shown in the top row of Table 1. Different TE pairs were used to compare the SNR of T2 map in each protocol, specifically the following TE pairs were used: SE 10/30ms, 10/60ms, 10/130ms; FSE: 12/30ms and 12/57ms. All other imaging parameters are the same for all scans, which are: TR=2500ms, slice thickness 7mm, FOV 24×24cm, matrix size 256*256, NEX 1. All SNRs shown in the table were calculated as defined above.

In vivo study Eighteen volunteers with atherosclerosis plaques were scanned twice - after obtaining their written consent forms - within two weeks for reproducibility test. FSE protocols with different echo spacing were used. Ten randomly chosen subjects were scanned with 20ms echo spacing and the rest with 42ms (optimized protocol). Other imaging parameters are: TR=2700 ms, slice thickness 2mm, FOV 16cm*16cm, matrix size 256*256, NEX 2.

Evaluation T2 maps were generated on a pixel-by-pixel fashion according to Eq.1. For phantom scan, SNR for each phantom were calculated and compared. For *in vivo* study, T2 histograms were prepared for each scan [3], and then correlation coefficient between the two histograms was calculated as a measure of reproducibility. In the statistical study, unpaired t-test was conducted to compare the correlation coefficients between the two groups.

Results:

Phantom study As shown in Table 1, for both SE or FSE sequences, if the echo spacing is optimized according to Eq.2 (Labeled by '*'), much better SNR can be reached than if not.

Table 1 Phantom SNR measurement under different imaging protocols

SNR	#1 T2: 46.33ms	#2 T2: 53.44ms	#3 T2: 171.70ms
SE (Δ = 20ms)	81	65	41
* SE (Δ = 50ms)	106	112	66
SE (Δ = 120ms)	31	36	107
FSE (Δ = 18ms)	51	38	12
* FSE (Δ = 45ms)	67	61	34

Table 2 *In vivo* reproducibility comparison under different imaging protocols

	Number	Mean Correlation	Std. Dev.	P-value
FSE (Δ = 20ms)	10	0.887	0.076	0.024
FSE (Δ = 42ms)	8	0.955	0.029	

In vivo study As shown in table (Table 2), for patients scanned with the optimized echo spacing protocol, significantly higher correlation were observed between two scans, which indicates a higher reproducibility.

Conclusions:

In this study, factors that affect the SNR of T2map were analyzed theoretically. Echo spacing value is then optimized for atherosclerosis imaging. Both phantom SNR study and in vivo reproducibility measurements agree with the theoretical analysis. This study will greatly enhance the reproducibility of the T2 mapping technique and the reliability of MRI tissue characterization.

Reference:

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