Practical Requirements for Bi-exponential T2* fitting in Achilles tendon Measured by Variable Echo Time Sequence

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Introduction:

Bi-exponential fitting of T_2* in Achilles tendon (and other highly organized tissues) by separating different T_2* components may improve the diagnostic reliability of these tissues[1]. Unlike mono-exponential T2* calculation, the bi-exponential calculation is more computational demanding and, more importantly, technologically more difficult (sequence, fitting algorithm, evaluation)[2]. This study provides a statistical analysis of requirements on SNR and other parameters (a difference between short and long T2* components) of bi-exponential T_2* analysis of healthy and diseased Achilles tendon.

Materials and Methods:

Mathematical phantom consisting of a calculated circle object with defined short and long T_2* component (0.5 and 15 ms) as well as data from 10 volunteers and 10 patients with Achilles tendinopathy were used. For quantitative mono- and bi-exponential T_2* assessment (T2*m, T2*s, T2*l), a multi-echo, variable echo time (me-vTE)[3] sequence was performed with twenty echo times TE from 0.8 to 20.1 ms. Other parameters were set as follows: field of view, 118 x 180 mm; matrix, 168 x 256; section/slice - thickness, 0.7 mm, 320 Hz/pixel bandwidth; 144 sections. All T_2* calculation were performed repeatedly with different noise levels (noise had Rice distribution, Fig. 1). Also, the condition for distinguishing short and long component ($m \times T_2$*s > T_2*l, [Eq.1]) was set for a range of *m* from 0 to 20 in step of 1. In case of phantom, the variability of T_2*s, T_2*l and T_2*m was evaluated, in case of human subject, the ability to distinguish between healthy volunteers and patients was analyzed (using unpaired t-test with equal variances) for all combinations of *m* and SNR.

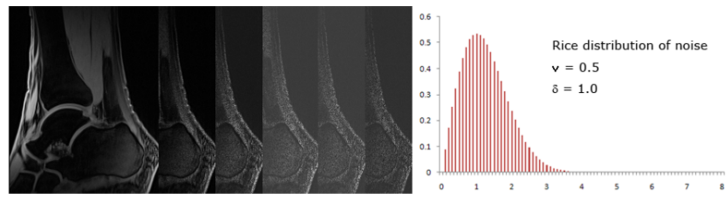

Figure 1. Example of simulated noise images of AT - noise distribution was considered Rice (images are equally scaled)

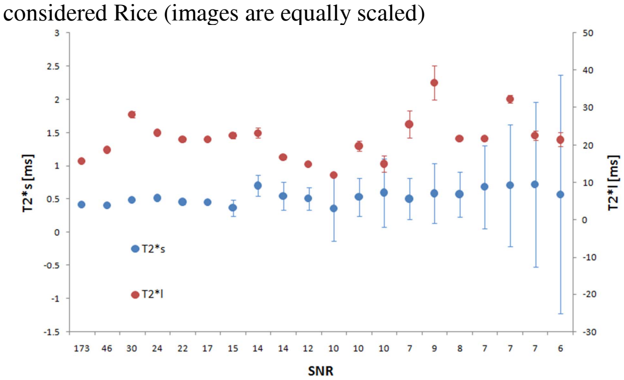

Figure 2. Bi-exponential analysis of phantom at different noise levels. In case of T2*s, the variation of the value is too high with SNR below 15. In case of T2*l, the standard deviation did not change substantially, however, the variation in absolute value was increasing with decreasing SNR.

Results:

Results of the mathematical phantom are summarized in the Fig. 2. It seems that the calculation of T_2*l is more noise-resistant compared to T_2*s, however, the estimation of T_2*s is quite stable with decreasing SNR despite of increasing standard deviation. Fig. 3 demonstrates the importance of considering limits for T2*l and T2*s (Eq.1) in bi-exponential T_2* calculation - the values in range 2 to 7 have similar statistical reliability ($p \ll 0.05$).

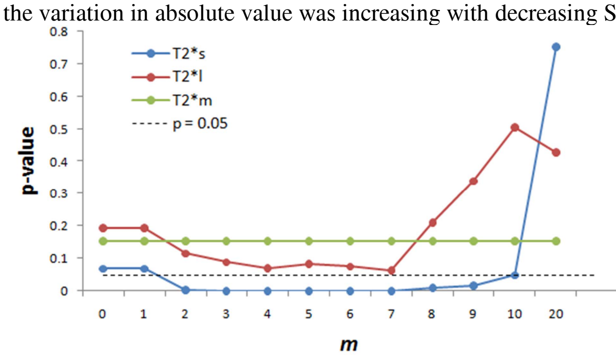

Figure 3. The p-values between patient and volunteers for T2*s, T2*l and T2*m calculated by unpaired t-test.

Discussion:

The results of this study provide a guide how to perform the bi-exponential T_2* fitting in Achilles tendon. Besides the usual conditions used in bi-exponential fitting (such as SNR and R^2 threshold), other conditions such as limits for the ratio of T2*s and T2*l obtained by fitting should also be considered for calculating reasonable T_2* values. The results of this study can be extended also to other tissues (menisci, ligaments, nerves) and is method independent (works with radial 2D and 3D-UTE, AWSOS, SPRITE).

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References: 1. Juras et al., Eur Radiol (2013) 23:2814–2822; 2. Du et al. MRM, 67:645–649 (2012; 3. Deligianni, X et al. MRM, In Press, 2012