Self-Justification Fitting to Improve Reliability of Relaxometry Quantification

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INTRODUCTION: Over decades, T1- and T2 quantification have been widely used in clinical routine diagnosis, e.g. evaluation of musculoskeletal cartilage, cardiac function and so forth [1-2]. Unlike qualitative gray-scale images, like T1W, T2W or DWI, diagnosis relies objectively on absolute T1, T2 quantization rather than subjectively on judging gray-scale differences. However, in practice, even a small system performance imperfection might not affect reading of gray scale images but will have a potentially large impact on quantified mapping values. Therefore, the reliability of quantified values should be ensured within an acceptable error range before being used for clinical diagnosis. Due to current technical limits, the system performance is usually imperfect at some level. In particular, for multiecho readouts, RF imperfections will introduce the first echo signal error due to imperfect slice profile, while the 2nd echo signal might be too high due to the stimulated echo effect. In fact, stimulated echoes will affect all even echo signals, particularly for those species with long relaxation time. If we look at the software sold on commercial scanners today, all MR manufacturers treat all acquired echo signals evenly when calculating T1 and T2. Although some in the past have debated RF profile effects, e.g. proposing to discard the first echo signal for T2-mapping, its implementation has not yet arrived in any conventional MR systems. Based on previous work regarding SNR, imaging time vs. accuracy [3,4], this work mainly focuses on system performance and data processing vs. accuracy of the quantified values, attempting to predict measurable quantification range. We also propose a self-justification fitting method in order to optimize these quantitative imagine results in the presence of system imperfections.

THOERY: Considering a noise-free and ideal system performance situation, using any n ≥2 points in the echo train to calculate T2 should always provide the same results, i.e. these calculated values' standard deviation should be zero, σ_s=0. On the other hand, let us assume we have a train with one bad point that is significantly deviated from the ideal curve due to system imperfection and/or noise. If this point is included in the fit, the σ_s will certainly increase. However, this means that the σ_s will be zero again for any other combination of n points without this bad point. Therefore, by calculating the fit for many different combinations of different points, we can choose combinations with the minimum σ_s, which will automatically detect and exclude bad points and improve the reliability of the fitted results.

Based on this concept, many different combinations of echo signals are used to calculate the T2 values for each pixel, e.g. echoes 1-8, 2-7, 3-6, and so forth. Standard deviations of each echo across the different combinations σ_s are then calculated. The minimum σ_s can be found and used to determine which echo signals should be discarded and which combination is optimal to obtain reliable T2 values.

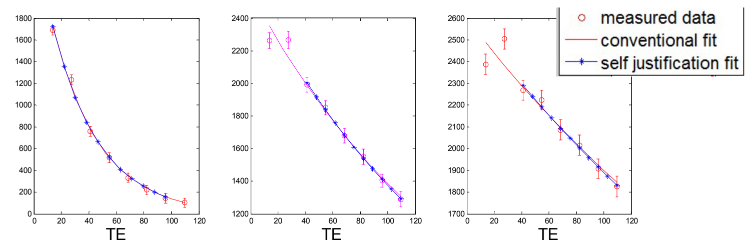

Fig.1: Measured and fitted T2 decay curves for 3 different T2s. The conventional/self justification fitting results are T2 = 32.8/33.2, 171.2/159.0, and 954.8/710.3 ms. In this case, significant deviations are seen at the higher T2 values.

METHODS: Phantom studies were performed on a 1.5T (Espree) with a 12-channel head coil. For T2-mapping, a multiple contrast phantom (T2 ranges from 33 to 1076 ms) and a conventional Spin-Echo multiple contrast (se-mc) sequence were used. Reference imaging parameters were: FOV =180mm, slices=3, thickness=3.0mm with gap = 6 mm, matrix=256 x 256, phase=LR, partial FT = 5/8, TR = 2000 ms, BW = 225 Hz/pixel, NEX=1, 8 echoes with TE = 13.7, 27.4, 41.1, 54.8, 68.5, 82.2, 95.9, 109.6 ms, respectively. T2-maps are then calculated by using scanner product software with linear fitting and using MATLAB for non-linear fitting.

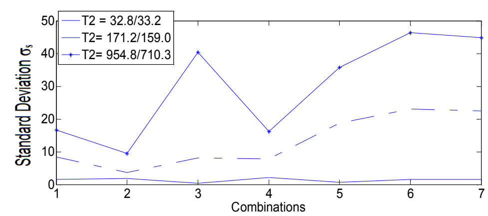

Fig 2: Standard Deviations as a function of seven different echo signal combinations.

RESULTS & DISCUSSIONS: Figure 1 shows the measured T2 decay signal from three species with different T2 values and compares the conventional fitting results when all echoes are included with the results from the self-justification fitting results when some of the points are automatically excluded. The non-ideal RF performance has more influence on those species with longer T2 than those with shorter T2. There is minor difference between conventional and self-justification curves when T2 = 33ms, but this difference becomes bigger when T2 value increases. Figure 2 shows standard deviation σ_s calculated from seven echo combinations. The σ_s is divided by 10 for display purpose when T2=710ms. The second combination which excludes the first two echoes has the minimum σs when T2 = 710ms and 159ms. All σ_s are lower than 2 when T2 = 33ms and the minimum σ_s is obtained when the last echo, which may be affected by noise, is excluded from fitting.

CONCLUSIONS: The effects of system performance vary among different tissues. Species with shorter relaxation time are more vulnerable to SNR rather than system imperfections due to fast signal decay while species with longer relaxation times are more sensitive to system imperfections rather than SNR. Therefore, for a given measured data set, our proposed self-justification fitting can be used to automatically exclude those data points whose errors are out of range. Our further work will extend this method to T1 quantification and will focus on a simple and fast calibration method for sequence related system performance imperfection in daily clinical routines.

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