Sources of quantitative error in T2 mapping of articular cartilage.

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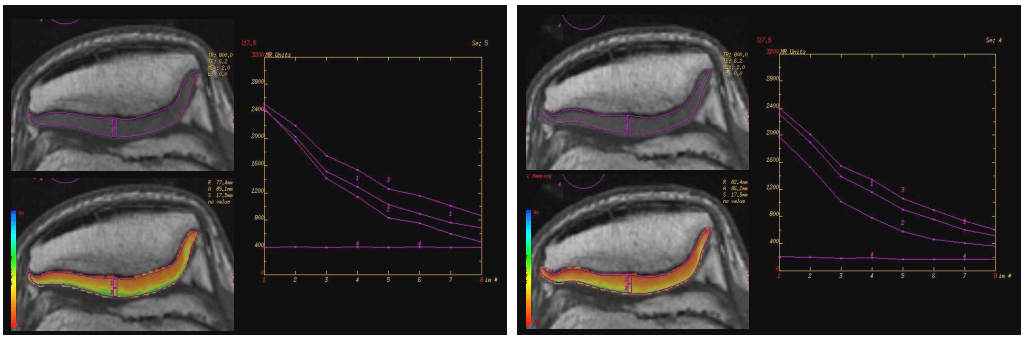
Introduction / Background: T2 relaxation time reflects the loss of transverse magnetization as a result of local tissue properties and inhomogeneities of the external magnetic field *(1)*. Quantitative T2 mapping has been shown in high field MR microscopy systems to correlate with collagen orientation *(2,3)*. If such quantitative analysis is to be utilized for longitudinal assessment, it is crucial that care is given to minimize potential sources of error. The purpose of this study was to present our observations of potential sources of error in quantitative measurement that can occur either at the time of imaging or post processing.

Materials and Methods: *Phantoms:* Two T2 phantoms composed of copper sulphate-agarose gel in sealed plastic containers, with known calculated T2 values of 30 and 60 msecs at 1.5T field strength, as well as clinical subjects, were imaged. *Image acquisition:* All MR imaging was performed on clinical 1.5 T or 3.0 T units (Twin Speed, General Electric Healthcare, Milwaukee, WI). T2 mapping was performed using a multislice, multiecho modified CPMG pulse sequence, which utilizes interleaved slices and tailored refocusing pulses to minimize contribution from stimulated echoes *(4)*. Standard T2 mapping pulse sequence parameters used were a repetition time (TR) of 800msec, eight echoes sampled using sequential multiples of the first echo time (9-10 msec). *Data analysis:* For all experimental data, a monoexponential decay was assumed. Following image acquisition, datasets were analyzed on a pixel-by-pixel basis with a 2 parameter weighted least-squares fit (Functool 3.1, GE Healthcare, Milwaukee WI). Quantitative T2 values were calculated by taking the natural logarithm of the signal decay curve in a selected region of interest (ROI). ROI's were obtained in a standardized fashion, within a fixed area from the center of the phantoms or at the same site in clinical subjects.
Analysis of the effect of selected variables: The effect on quantitative T2 relaxation times of the following factors was explored: 1) Different coils (single vs multichannel); 2) Use of parallel imaging to identify elements with increased noise (ASSET); 3) The effect of different field strengths; 4) Difference in data acquisition (interleaved slices in two acquisitions vs sequential slices in a single acquisition); 5) Effect of the number of echoes sampled (8 vs 16); 6) Effect of different data analysis algorithms, including use of a 2 vs 3 parameter fit; i.e., $y(t) = ae^{-bt} + c$ (IAW, ASL, GE Healthcare, Milwaukee WI) .

Results: 1) The use of different coils (single channel quadrature vs 8 channel phased array knee coil, without the use of parallel imaging) resulted in no significant differences in T2 values for either the 30 or 60 msec phantoms. This was not so, however, for clinical subjects, where an increase of 37 - 47% in quantitative T2 values were demonstrated with a multichannel coil. 2) The use of parallel imaging (ASSET) with acceleration factors of 1.25 and 2 did not cause a significant difference in T2 values for both 30 and 60msec phantoms, despite a marked reduction in the noise floor (by 61%). In clinical patients, the use of an acceleration factor of 1.25 reduced the noise floor by half, but also reduced quantitative T2 values by 18-22% *(Figure 1)*. 3) Imaging at 3T compared to imaging at 1.5T resulted in T2 values that were lower (by 10.2%) for the 60 msec phantom, but not significantly different in values for the 30msec phantom 4) When sequential image slices with a 20% slice gap were obtained using a single acquisition, phantom imaging demonstrated slightly elevated T2 values, compared to interleaved slices with no slice gap in 2 acquisitions. This elevation using a interslice gap in single acquisition scan was accentuated in clinical subjects, where up to 25.8% increase in T2 values of normal cartilage was encountered. 5) The use of 16 vs 8 sampled echoes resulted in no differences in T2 values for the phantoms. 6) When a 3 parameter mono-exponential analysis of the phantom data sets was used, in comparison to a 2 parameter fit, reduced T2 values were noted for the 60msec phantom (by 6.6 – 7.0%) but increased T2 values were seen in the 30 msec phantom (by 7.4 – 9.3%). In addition, the standard deviations of the T2 values were increased for both phantoms using the 3 parameter fit. However, measured T2 values approached that of phantoms, with a relatively smaller standard deviation, using the 3 parameter fit algorithm, when 16 sampled echoes were obtained compared to 8 sampled echoes.



A B

Figure 1: Clinical axial color-coded quantitative T2 maps and signal decay curves for selected regions of interest without (A) and with (B) the use of parallel imaging (acceleration factor of 1.25). Note the substantial reduction in noise floor, as well was the shortening of T2 values within the articular cartilage of the patellofemoral joint.

Conclusion: When performing quantitative imaging analyses, it is imperative that any potential sources of quantitative error are identified and minimized, both at the time of scanning, as well as during post processing of data. Elevated noise floor in the multichannel coil may factitiously elevate T2 values; this can be corrected using coil sensitivity profiles in parallel imaging. When parallel imaging is not used, the traditional sum-of-square image reconstruction artificially enhances the noise floor, hence introducing a noticeable bias in the signal amplitude of the late echoes. The use of three parameter fit did not consistently improve accuracy over a two parameter fit, except when also accompanied by an increase in the number of echoes sampled, at the expense of additional scan time. Altering these various parameters on phantom imaging may not predict the effect on measured T2 values in clinical subjects, and it is recommended that pilot data be obtained to assess reproducibility before longitudinal quantitative assessment of patient cohort. Standardization of parameters, field strength and coils within patient sets is also imperative to reduce error.

References:

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