A model-based approach for fast T2 mapping of articular cartilage

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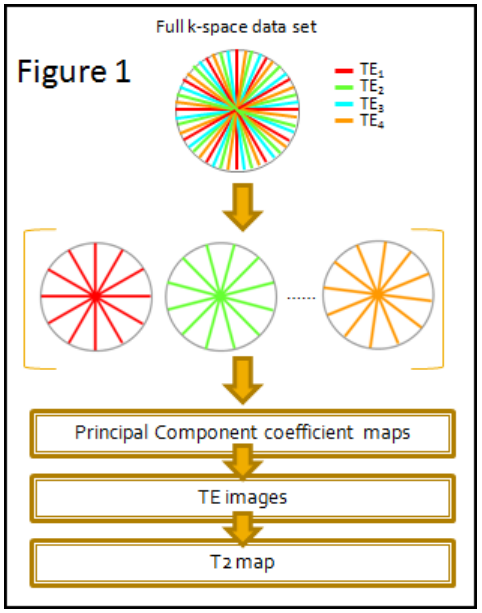
Introduction: Quantitative T2 measurements have been explored for evaluating articular cartilage and a correlation between increasing T2 values and cartilage degeneration has been observed (1). Conventional multi-echo imaging techniques have been used for cartilage T2 mapping. However, the acquisition of data with adequate spatial resolution requires long scanning times. Reducing acquisition time is generally done at the expense of temporal resolution (i.e., small number of TE points), lower spatial resolution, lower SNR, or reduced number of slices. In this work, we demonstrate the ability to use a Principal Component Model-based algorithm recently developed by our group (2) to reconstruct high resolution T2 maps of cartilage from highly undersampled radial Fast Spin-Echo (FSE) data, hence achieving multi-fold acquisition time reduction.

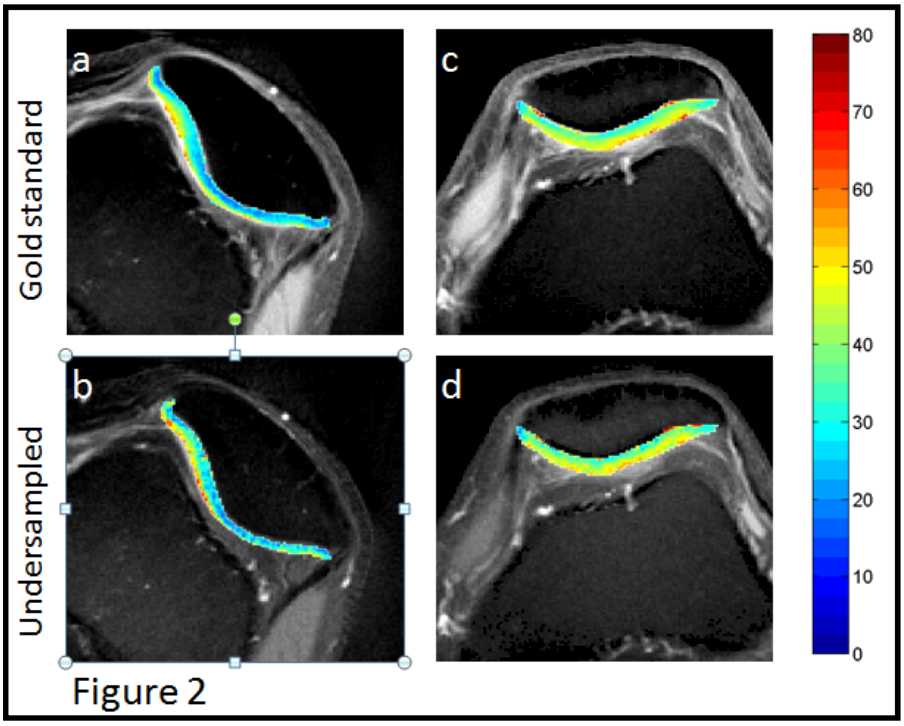


Methods: A schematic representation of the Principal Component Model-based algorithm is shown in Figure 1 where a full radial FSE k-space data set is divided into partial sets at the specific TEs (number of TE data sets equals the ETL). TE images are obtained from the partial k-space data sets from Principal Component coefficient maps which are reconstructed using an exponential decay model in an iterative manner (2). A T2 map is then calculated from the reconstructed TE images.

This algorithm uses the principles of the recently developed Compress Sensing theory to improve T2 estimation by taking advantage of the spatial and temporal sparsity of the TE images. It was shown in (2) that 3 Principal Component can characterize the T2 decay accurately (for either a single or multi component species). By using 3 coefficients instead of 8 TE images, the temporal sparsity is exploited. The spatial sparsity is enforced in each of the 3 coefficient maps.

To test the model-based approach for T2 mapping of cartilage two asymptomatic young male were imaged. All data sets were acquired at 1.5T (GE Signa NV-CV/i scanner) using a radial FSE sequence with a single channel transmit/receive coil. Some of the acquisition parameters are: echo spacing = 8.29 ms, ETL = 8, TR = 2s, slice thickness = 5 mm, NEX = 2, receiver bandwidth = ±31.25kHz, FOV = 16 cm. Flow from large vessels was suppressed via saturation bands. For the undersampled data set, an acquisition matrix of 256(frequency)×256(phase) was used, resulting in 32 k-space lines per TE and a total imaging time of 2 minutes and 12 seconds. Gold standard T2 maps were also obtained from radial FSE data acquired with 256 k-space lines for each TE. The acquisition of gold standard data was 17 minutes and 8 seconds.

Results: Figure 2 shows the T2 maps of patellar cartilage (***color map***) overlaid onto the corresponding anatomical T2 weighted knee images. Although 8 times less data were used in the images reconstructed from undersampled data (***bottom***) compared to the gold standard images (***top***), the T2 maps are comparable. As reported previously, there is a progressive increase in the T2 from the radial to the superficial zone of the cartilage (3). This is seen in both the gold standard and undersampled T2 maps.



For the purpose of quantitative comparison, we calculated the mean T2 and standard deviation of the cartilage ROI. The mean and standard deviation of the gold standard map for one of the volunteers (Figure 2a) were 32.6 ms and 9.5 ms, respectively. The corresponding values obtained from undersampled data using the model-based approach (Figure 2b) were 34.8 ms and 10.9 ms, respectively. For the second volunteer, the values are also comparable: 42.7ms ±7.2ms (Figure 2c) and 43.0ms ± 7.0ms (Figure 2d).

Conclusions: We demonstrated the ability to obtain accurate T2 maps of patellar cartilage from highly undersampled data using a Principal Component model-based algorithm. This approach significantly reduced the acquisition time to obtain the T2 maps (from ~17 min to 2 min), and yields comparable result to the gold standard. Reducing acquisition time does not only improve patient throughput and increase patient comfort, but also reduces sensitivity to motion which should improve the quality of images required for T2 mapping.

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References: 1. Lammentausta E, et al. J Orthop Res, 2006, 24
2. Huang C, et al. Proc. ISMRM 2009, 348
3. Dardzinski BJ, et al. Radiology, 1997, 205.