# Accelerated T2 Mapping of Articular Cartilage Using Iterative HYPR

**J. J. Jacobson[1], R. O'Halloran[1], A. A. Samsonov[2], R. Kijowski[3], S. B. Fain[4], and W. F. Block[5]**

[1]Medical Physics, University of Wisconsin Madison, Madison, WI, United States, [2]Radiology and Medical Physics, University of Wisconsin Madison, Madison, WI, United States, [3]Radiology, University of Wisconsin Madison, Madison, WI, United States, [4]Biomedical Engineering, Medical Physics, and Radiology, University of Wisconsin Madison, Madison, WI, United States, [5]Biomedical Engineering, and Medical Physics, University of Wisconsin Madison, Madison, WI, United States

**Introduction:** The early stages of cartilage degeneration are characterized by a reduction in the collagen and proteoglycan content and an increase in the water content. These changes can be indirectly quantified through T2 mapping to demonstrate degeneration before it is evident on morphological imaging. To fit the signal decay with *n* sample points along the T2 decay parameter, conventional mapping methods require an *n*-fold increase in scan time. These long scan times limit the use of mapping in clinical imaging and monitoring osteoarthritis treatment trials. Instead of treating each voxel in the parametric images as independent data, we utilize an iterative constrained reconstruction method, termed Iterative Highly constrained Back Projection (I-HYPR) [1], and undersampled radial imaging to exploit redundancy, limit sampling, and accelerate mapping. Using data from a conventional fully sampled T2 mapping sequence, we subsample the acquisition to simulate a four-fold speedup and determine accuracy by using the fully sampled map as a gold standard.

**Methods:** *Algorithm:* We utilize the HYPR [2] concept that exploits correlations in a temporal series of images, but substitute parametric data for temporal data. Instead of fully sampling each T2-weighted image in the parametric series, a composite image is built from subsampled data at multiple echo times and used as a constraint. Unlike the initial single iteration HYPR algorithms whose approximate nature caused some blurring, cartilage imaging requires more accuracy to evaluate relatively thin articular surfaces. Therefore, the composite image is iteratively altered to create consistency with the subsampled data from one echo time using the I-HYPR method, illustrated in Fig. 1. After this process is replicated to construct an image for each T2-weighting for which subsampled data is acquired, a T2 map is generated.
*Simulation*: Fat-saturated 2D T2-weighted images were obtained at 8 echo times (8, 16, 24, 32, 40, 28, 56, and 64 ms) using a Cartesian RARE sequence (8:36 scan time). The 256 x 256 images were acquired on a GE 3T magnet with an 8 channel knee coil. A 2:00 scan was simulated by computing a set of 60 subsampled projections from the original RARE images at each echo time, as illustrated in Fig. 1, and then using the I-HYPR algorithm with three iterations to reconstruct each echo time frame. The reduction in encodings corresponded to a speedup factor of 4.2. Standard curve fitting methods generated the T2 maps for both the conventional and accelerated methods.

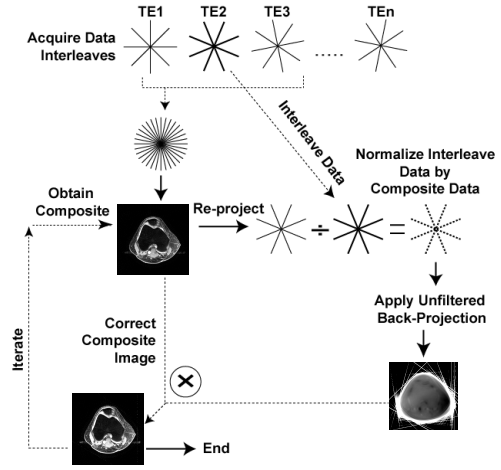


**Figure 1:** Diagram of I-HYPR algorithm [1].

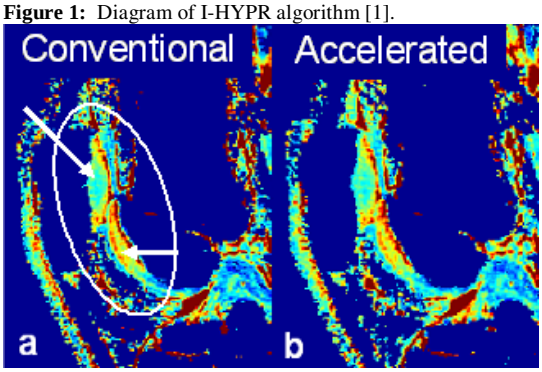


**Figure 2:** Comparison of sagittal T2 maps of patellar (long arrow) and femoral (short arrow) cartilage (in ms, same scale as Figure 2) in an asymptomatic individual show strong similarity between the slower and accelerated method.

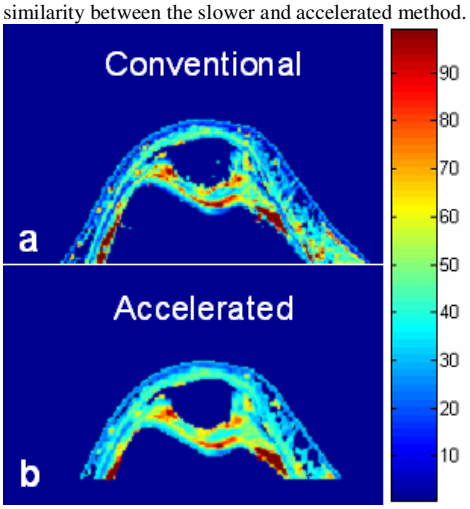


**Figure3:** Axial T2 maps of patellar cartilage (in ms) in a volunteer with OA for the conventional method (a) and the simulation of the I-HPYR method (b) show elevated T2 at the surface of the bone/cartilage interface of the patella.

**Results and Discussion:** Conventional and accelerated T2 maps were created for an asymptomatic subject in the sagittal plane (Figure 2) and a subject with osteoarthritis (OA) in the axial plane (Figure 3). The accuracy of the accelerated T2 maps was computed by calculating the RMS error, using the conventional map as a gold standard, over 611 pixels containing cartilage. The accelerated method had an RMS error of 9.5% for the asymptomatic knee and 11.6 % for the OA knee. The minimum achievable error, which may also be considered as moderate blurring, is limited by the number of iterations that I-HYPR can perform without noise amplification. Much of this amplification results from moving back and forth between k-space and the image space using gridding operators. Methods for reducing these errors have allowed for an increased number of iterations [3] and would likely further reduce reconstruction errors. We note that a similar methodology could accelerate T1ρ imaging.

**Conclusion:** A method for constructing T2 maps from a set of highly undersampled images with an acceleration factor of 4 and a moderate error has been presented. While parallel MRI can also accelerate scanning, its SNR loss affects the accuracy of shorter T2 tissues. The I-HYPR method preserves the SNR from a much longer acquisition by using it as a constraint. Extending this method to incorporate parallel MRI would likely allow further acceleration.

**References:** [1] O'Halloran, Fain, et al. MRM in press. [2] Mistretta et al. MRM (2006). [3] Park et al. MRM (2005).

**Acknowledgments:** We acknowledge the support of Medical Education Research Committee funding and GE Healthcare.