Optimization of a 3D Phase-Sensitive IR protocol for DGEMRIC technique.

M. Durkan[1], J. Szumowski[2], D. Brown[1], D. Crawford[1], E. Schwarz[2], and K. Heiles[3]
[1]Orthopaedics & Rehabilitation, Oregon Health & Science University, Portland, Oregon, United States, [2]Radiology, Oregon Health & Science University, Portland, OR, United States, [3]Hewlett Packard, United States

Introduction:
Delayed Gadolinium Enhanced Magnetic Resonance Imaging of Cartilage (DGEMRIC) is a well-established procedure with a potential to quantitatively measure the fixed-charge density (FCD) of proteoglycan aggregates [1]. Multiple DGEMRIC sequences have been developed to generate T1 maps [2] which in turn can be used to assess cartilage integrity. Among the methods used for T1-mapping the Inversion Recovery (IR) based methods are the most reliable, however, at the expense of the long acquisition times. Time constraints associated with image acquisition and post processing make routine DGEMRIC exams clinically unattractive. One factor contributing to the long scan time of DGEMRIC IR is the number of inversion times TI's. We have recently developed a phase-sensitive algorithm for processing DGEMRIC IR sets of image data [3]. The new method doubles the dynamic range of image data available for T1 fitting and therefore it could potentially allow for a smaller number of TI points needed for accurate T1-mapping. We will demonstrate that using this phase-sensitive algorithm the number of IR's can be reduced to four, leading to a total exam time of less than 10 minutes, without sacrificing T1-fit accuracy.

Methods and Results:
3D IR dGMERIC images were acquired on a Philips 3.0 Tesla MRI scanner using an 8-channel knee coil with following sequence parameters: TR/TE 5.1/2.6, 52 shots, shot interval 2800, flip 15, FOV 180x160, matrix 256x200, recon voxel 0.5x0.5x1.5, 62mm slab, bandwidth 434 Hz/pixel, resulting in scanning time of 2:26 min per inversion time TI. 3D IR series included a set of seven IR times: 40, 100, 300, 600, 1000, 1500, 2200 ms.
The phase-sensitive algorithm was applied to sagital post-Gd IR images using custom software developed in MATLAB (version 7.10, Mathworks, Natick, MA, USA). Phase sensitive and standard Modulus data were fit to the following equation: $I_Z(TI) = I_0*(1-A*\exp(-TI/T1))$. T1 values calculated from fitting seven TI were designated as Controls. Subsets of three, four, or five TI's were chosen for curve fitting. The fitting routine was adjusted to flag bad pixels when the R-squared (R^2) fit statistic was less than 0.98.

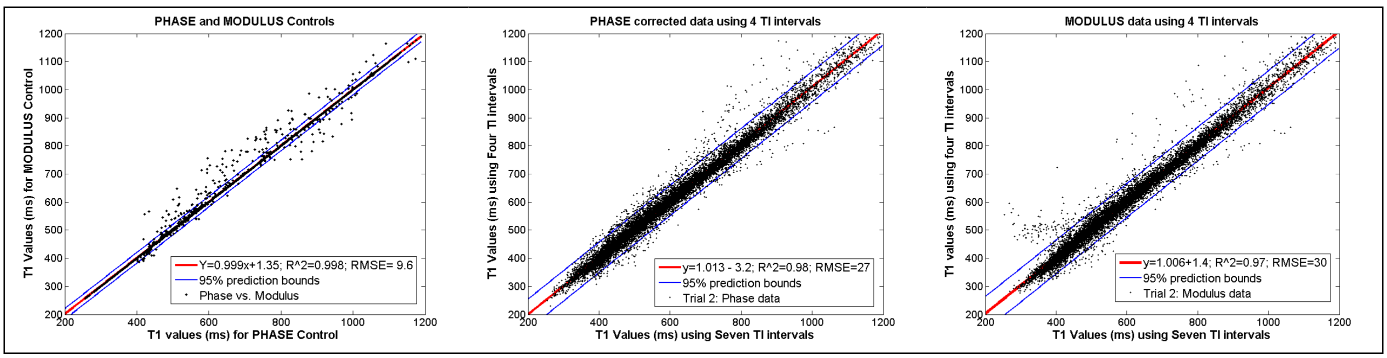

Figure 1. The left graph is a linear comparison of Phase and Modulus Controls. The middle and right scatter plots represent T1 values from fitting four TI.

Table 1. Statistical analysis of 12,406 T1 values from fitting three, four, or five TI intervals

Trial	Inversion Times, ms	Bad Pixels		Trendline R^2		RMSE	
		Phase	Modulus	Phase	Modulus	Phase	Modulus
1	40, 600, 2200	120	764	0.92	0.93	53	49
2	**40, 300, 1000, 2200**	**133**	**1010**	**0.98**	**0.97**	**27**	**30**
3	40, 100, 300, 1500, 2200	134	864	0.96	0.97	38	33
4	40, 300, 600, 1000, 2200	89	784	0.97	0.97	33	31

Results in Table 1 show Trial 2 had the strongest correlation to Controls but Modulus data produced a large number of bad pixels. (R^2=0.98-0.97, RMSE=27-30, N=12,406). Modulus Control data produced 680 bad pixels while Phase Control data produced 42 (N=12,406).

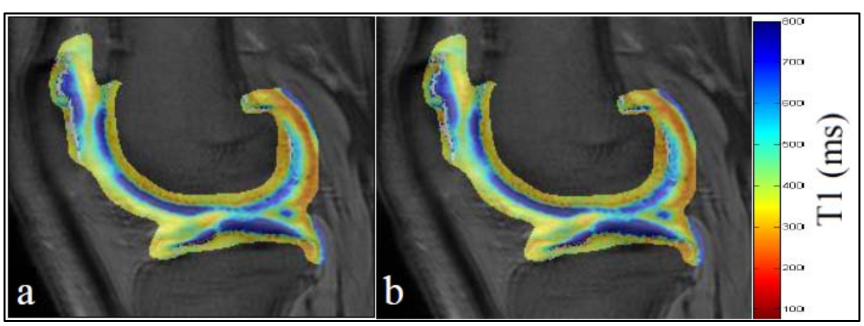

Figure 2 shows T1 color maps generated from Phase sensitive data using seven TI intervals (**Fig. 2a)** and four TI intervals (**Fig. 2b).**

Conclusions and Discussion:
Decreasing the number of inversion times to four and applying a phase-sensitive reconstruction algorithm allows reliable calculation of T1 relaxation maps. In contrast to phase-sensitive IR data, a significant number of pixels processed using a Modulus of the equation failed curve fitting. Optimization of the current 3D IR DGEMRIC protocol with four instead of seven TI would decrease clinical acquisition times to less than 10 minutes.

References: [1] Burstein D., et al. *Radiology*. 1997; 205(2):551-558. [2] Siversson C, et al. *J Magn Reson Imaging*. 2010; 31(5):1203-1209. [3]Szumowski J., et al. ISMRM 2011.