Iterative T2 Estimation from Highly Undersampled Radial Fast Spin-Echo Data

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Introduction: Recently radial methods have been investigated as a means to obtain MRI-dependent tissue parameters such as T2 and T1 from a single k-space data set[1,4]. These methods permit the fast measurement of tissue parameters. So far the approach to derive tissue parameter maps from a single radial k-space data set are based on an echo-sharing (or key hole) algorithm where data in the center of k-space is weighted to a specific TE or TI with the rest of the data added in the outer part of k-space. Depending on the number of radial views collected, the echo sharing approach can lead to significant errors for objects with high spatial frequency content. In this work we present an iterative algorithm based on Projection onto Convex Sets (POCS) to estimate T2 maps from a single radial fast spin-echo k-space data set. The method yields accurate T2 estimates for small structures even for highly under sampled radial data.

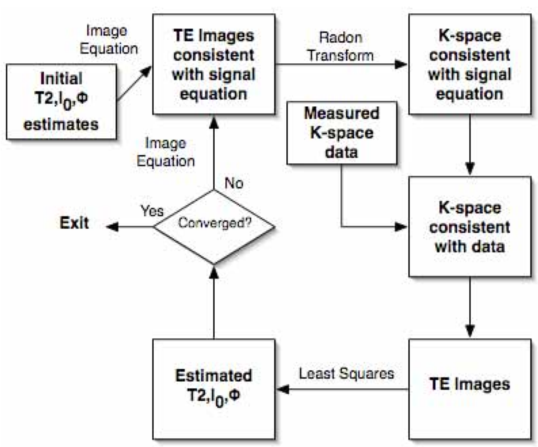

Figure 1. Iterative Method

Theory and Method: POCS is a well known reconstruction technique in the medical imaging field. If the object being reconstructed is subject to any constraints that can be formulated as convex sets, by alternatively projecting from one constraint to the next, one is guaranteed to converge to a point in the intersection of all the constraint sets, if such a point exists. For our data we have two constraints: the assumed form of the signal equation and the acquired k-space data. For T2-weighted data the signal equation expressed in a logarithm form is: $\ln[f(x,y,TE) = \ln[I_0(x,y)] - \frac{TE}{T2(x,y)} + i\phi(x,y)$ [1].

In [1] $I_0(x,y)$ is the equilibrium magnetization and includes coil factors, the proton density and T1 effects. The term $i\phi(x,y)$ is the complex phase in the images and is assumed to be independent of TE (our experimental evidence supports this assumption for fast spin-echo data). Since the real part in [1] is linear in TE and the imaginary part is a constant, for any image location (x,y), [1] is a convex set. Thus the projection operations are a linear least squares fitting of the real part and a simple average of the imaginary part. The second constraint, i.e. the known or "measured" k-space data is also a convex set, and the projection operation is to take the Fourier transform of the image and to impose the known data.

Based on these constraints we formulate an iterative algorithm to reconstruct T2 maps from radial k-space data (Fig. 1). Starting with an initial $T2$, I_0, and ϕ estimate we generate TE images consistent with [1]. After the Radon transformation operation we replace the estimated k-space data with the measured data. Now the TE images are generated from the modified k-space data consistent with the measured data. We then enforce consistency with [1] using least squares fitting. This gives new estimates for $T2$, I_0, and ϕ. We continue the iteration until convergence.

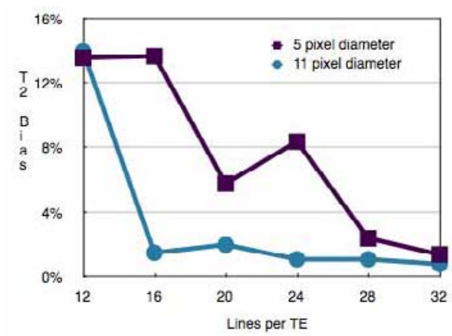

Figure 2. T2 bias vs. Lines per TE

Diameter (pixels)	Gold Std. T2 (ms)	Estimated T2 (ms)	T2 bias (%)
5	242.94	246.42	**1.4%**
5	180.36	184.2	**2.1%**
5	107.39	106.83	**0.5%**
11	237.49	234.84	**1.1%**
11	176.62	175.23	**0.8%**
11	104.1	103.65	**0.4%**

Table 1. T2 Estimation Results

Results and Discussion: To analyze our technique we constructed a phantom with tubes containing various concentrations of agarose gel. We collected two data sets for this phantom on a 1.5 T GE Signa MRI scanner. One data set consisted of 2048 radial views and ETL=8 (i.e., 256 views per TE). This larger data set was considered to be our gold standard. T2 maps were reconstructed in the normal non-iterative fashion. The other data set had 256 radial views with only 32 views per TE. The latter was used in our iterative technique to compare to the gold standard. Simulation data were also created using analytic Fourier expressions to which mean zero Gaussian noise was added at a level consistent with real data.

In all experiments we found that the T2 map stopped changing significantly after 15-20 iterations. Table 1 compares T2 estimates from the iterative method with 32 lines of data per TE to the gold standard for phantom data from a small (5 pixel diameter object) and a larger (11 pixel diameter) object. Note that regardless of the object size, there is excellent agreement with the T2 values of the gold standard (T2 bias within 2% or less). Figure 2 shows the accuracy of T2 estimates for extremely under sampled data. Even with as few as 12 lines per TE, we are able to obtain reasonable T2 estimates. Figure 3 shows a comparison of a T2 map generated from a data set acquired with 256 k-space lines per TE reconstructed normally (i.e., the gold standard) and a T2 map generated from a dataset of 32 lines per TE reconstructed iteratively.

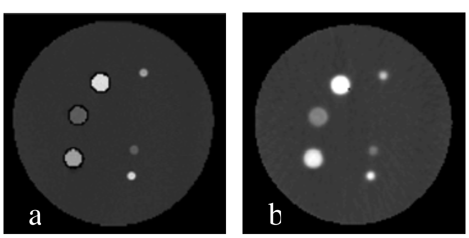

Figure 3. T2 map comparison between (a) gold standard and (b) iterative method

Conclusion: An iterative method to obtain accurate T2 estimates from under sampled radial fast spin-echo data was developed. This method shows great promise for achieving accurate T2 estimates with a minimal amount of scan time. The method can be extended to other radial MRI methods.

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References: [1] Song, MRM, 44, 825, 2000. [2] Altbach, MRM, 54, 549, 2005, [3] Griswold, ISMRM, 12, 2661, 2004. [4] Newbould, ISMRM, 13, 99, 2005.