INTRODUCTION

Nonlinear reconstruction for 3D spiral DTI acquisitions
- Reduce scan time of DTI acquisitions with undersampled 3D spiral acquisition [1]
- Combined PI/CS reconstruction with nonlinear variational constraints [2,3]
- Evaluate effects of nonlinear regularization on quantitative DTI evaluation

METHODS

Digital diffusion phantom
- Simulated volume based on LONI ICBM DTI-81 Atlas
- Additional resolution inserts, fibers in 3 cardinal directions, fiber widths 1-4 pixels
- Simulated on 180° grid, 32 coils, spiral projection k-space trajectory, 5000 arms
- Undersampling (R=4) by discarding 75% of the spiral arms
- Diffusion acquisition, 2 non-diffusion weighted and 15 different diffusion directions
- Two different levels of noise added to k-space data

TGV\(^2\) constrained image reconstruction
- Solve optimization problem for each individual diffusion encoding direction \(i\):
  \[
  \min_{u_i} \frac{1}{2} \| F(u_i) - k_i \|^2 + \alpha TGV^2(u_i)
  \]
- \(u_i\) is reconstructed 3D volume of images from single diffusion-encoding direction
- \(k_i\) is the corresponding 3D spiral k-space data
- \(TGV^2()\) is the penalty functional
- \(\alpha\) is a regularization parameter
- \(F\) is undersampled non-Cartesian sampling operator including coil sensitivities
- Comparison against gridding with density compensation

Analysis:
- FA maps and principle eigenvector maps computed from each volume
- The difference in FA from each map with the ground truth
- Angular difference of the principle eigenvector
- Computations performed only over pixels containing white matter tissue as defined by the LONI ICBM DTI-81 white matter mask

RESULTS

- FA maps from TGV\(^2\) quantitatively superior to gridding results at both levels of SNR (Fig. 1 a,b,f,g), especially in white matter
- Similar trend in the color FA maps (Fig. 1 c,d,h,i)
- Histograms of FA differences (Fig. 2a) and angular differences of principal eigenvectors (Fig. 2b) over white matter regions show that TGV\(^2\) has less error in both metrics at both SNR levels
- Most striking in FA: TGV\(^2\) at lower SNR lower error than gridding at higher SNR

DISCUSSION

- DTI both especially interesting due to long acquisition times and challenging due to limited SNR
- FA and principal eigenvector maps from TGV\(^2\) had less artifacts and were quantitatively better than gridding results for both levels of SNR tested
- Sharp edges of resolution inserts preserved with TGV\(^2\), indicating no loss of resolution in the constrained reconstructions
- Results suggest TGV\(^2\) could be used to help reduce lengthy 3D DTI protocols

REFERENCES


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Quantitative evaluation of 3D variational regularized reconstruction of undersampled diffusion tensor imaging

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