Fast Diffusion Imaging using Undersampled Propeller EPI

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INTRODUCTION

Diffusion weighted imaging using propeller sequences (PROPELLER-DWI) (1) has been suggested since it provides high spatial resolution combined with a high signal-to-noise ratio (SNR). However as of today, the scan time in any PROPELLER DWI (1) sequence will be the number of diffusion directions times the number of propeller blades needed to acquire a full k-space. This generates excessive scan times, especially in Diffusion Tensor Imaging (DTI). In this work a new DWI Propeller reconstruction is suggested that dramatically reduces the scan time when imaging multiple diffusion directions. The method was tested using Short Axis readout PROPELLER EPI (2), a sequence well suited for DWI and DTI scans.

METHOD

Ideally, when imaging multiple diffusion directions, tissue with anisotropic diffusion characteristics will get a contrast representing the applied diffusion direction. Tissue with isotropic diffusion will have an unchanged contrast independent of what direction is played out, as long as the b-value remains constant. If a set of diffusion directions are imaged and combined into one composite image, it will be anatomically correct, but not much can be said about the anisotropy. The proposed method uses the strategy of assigning one diffusion direction to fewer blades than what is required to grid a full resolution k-space. In the extreme case only one blade per diffusion direction. In order to maintain anisotropic contrast for a given diffusion direction, only data from that blade is used to cover parts of k-space for the corresponding blade location. This gridding process is shown in Figure 1. As means to reduce "leakage" between blades, which arises from the fact that each reconstructed direction rely on data from several diffusion directions, the order in which propeller blades were assigned diffusion directions were optimized; Orthogonal blades (i.e. blades far apart) were assigned diffusion directions with a small spatial angle (i.e. maximal absolute scalar product), adjacent blades were assigned diffusion directions with a large spatial separation (i.e. small absolute scalar product). Diffusion direction scheme optimization was set up as a travelling salesman problem and the solution was approximated using a simulated annealing method (3). The method was tested on a GE 1.5T Signa Twinspeed (Milwaukee, WI), using a SAP-EPI sequence (TE = 69.7ms, TR = 3000ms, matrix = 192x64, and b = 1000s/mm^2) with 10 blades and 10 diffusion directions. Reconstruction was done by using 1 blade per diffusion direction, 2 blades per diffusion direction, and all 10 blades for each diffusion direction as a comparison.

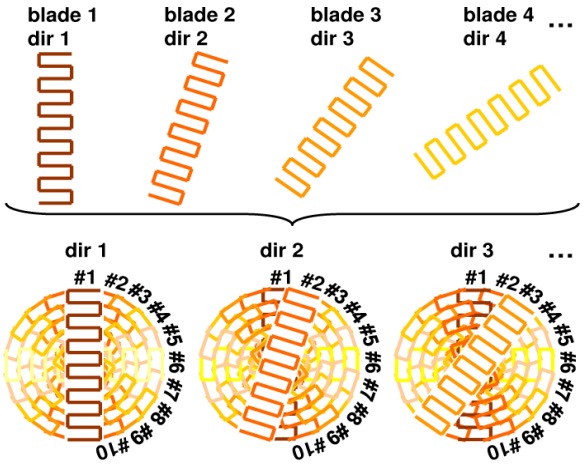

Figure 1: Propeller blade 1-4 (each with a unique diffusion direction, dir 1-4) and corresponding gridding process.

RESULTS

The method is able to create high resolution fractional anisotropy maps using a dramatically reduced scan time, something which is of great interest in clinical practice (where scan time is a limiting factor). A comparison between having same diffusion direction for all blades, same diffusion direction for two blades (giving blade 1 and 6, blade 2 and 7 etc. in Figure 1 same diffusion direction), and the extreme case when only one blade corresponds to one diffusion direction can be seen in Figure 2. In order to create a complete diffusion weighted data set the unreduced sequence requires a total of 11 volumes (1 T2-weighted and 10 diffusion direction encoded volumes). By reducing diffusion direction encoding to two blades per diffusion direction is the number volumes needed to be scanned reduced to 3, and in the single blade case are only 2 volumes needed.

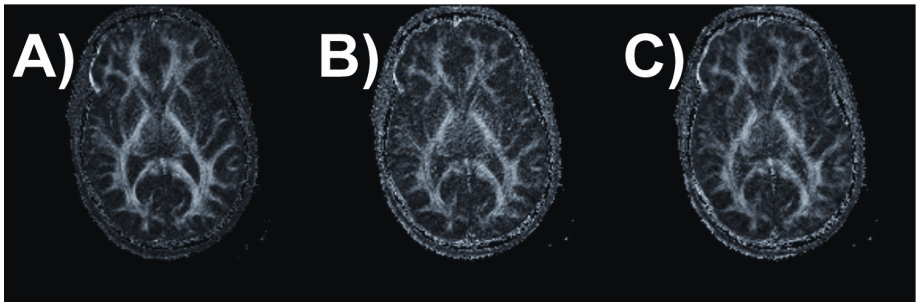

Figure 2: Fractional anisotropy maps calculated using A) All blades (1 diffusion direction applied to all blades) B) Crossing blades (2 blades per diffusion direction) C) Single blade (1 blade per diffusion direction)

DISCUSSION

The use of only one, or few, blades to cover the contrast giving parts of kspace sets high demands on the acquired data. In this sense a FSE readout, with its high robustness to distortions, could have been more beneficial than the fast EPI readout in SAP-EPI. To further improve this method a density compensation function with low sensitivity to density changes could be advantageous.

REFERENCES

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