Data Collection and Post-Processing Strategies in Radial-FSE for Diffusion Tensor Analysis

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Introduction

In radial MRI, Fourier data are collected on a polar grid and therefore lower spatial frequency k-space data are oversampled compared to higher spatial frequency data. By oversampling the low spatial frequencies, possibilities exist to extract and reconstruct multiple images from partial radial datasets. If radial lines have different weighting, reconstructed images from partial datasets can have different contrast. Techniques to produce images with differing amounts of T2 and T2* weighting from single radial fast spin echo (radial-FSE) and radial gradient and spin echo (radial-GRASE) acquisitions have been demonstrated [1-3]. In this work, a method for applying partial dataset reconstruction techniques to diffusion tensor imaging (DTI) is described. By controlling the appropriate diffusion weighting, orientation and order of radial lines within a single radial acquisition, it is possible to obtain data from which images can be reconstructed that have different directional diffusion weighting. From such data, isotropic and anisotropic diffusion properties can be calculated.

Methods and Materials

In a radial fast spin echo (radial-FSE) acquisition, multiple radial lines are collected within an echo train every TR. When a diffusion-weighted preparation period is employed, each echo train can be sensitized to directional diffusion independently. If diffusion weighting is altered throughout the acquisition amongst appropriate diffusion directions, data can be collected that allows calculation of diffusion anisotropy in partial datasets. In the present experiments, diffusion weighting was applied in six non-collinear diffusion directions throughout the examination. The collection order of radial lines (views) was controlled such that *i*) the entire 2л radians of k-space is coarsely sampled each echo train, minimizing artifacts from motion; *ii*) there is an even angular sampling of radial lines collected with each diffusion weighting direction and echo position (TE); and *iii*) there is no correlation between echo position and diffusion weighting direction. The dataset can be partitioned by diffusion direction, each partition consisting of only those radial lines weighted to the same diffusion direction. A diffusion tensor analysis may be performed on these datasets. Alternatively, the full dataset can be reconstructed to an effectively isotropic diffusion weighted image.

Results and Discussion

Diffusion-weighted radial-FSE datasets were acquired from a healthy volunteer on a GE Signa LX 1.5T Echospeed clinical scanner. Figs 1a, 1b, and 1c show colorized diffusion tensor eigenvector maps and Figs 1d, 1e, and 1f show the corresponding relative anisotropy (RA) maps. Figs 1a and 1d were produced from six full 256 x 792 view data sets, obtained in the conventional manner, with a total scan time of 20 minutes (TR=1500ms, ETL=6, 8 slices). The high resolution and signal-to-noise ratio (SNR) of this acquisition allows even fine structures like the anterior limb of the internal capsule to be clearly visible. Figs 1b and 1e show the resultant anisotropy maps from a radial dataset with 396 views acquired per diffusion-weighting direction (a total of 2376 radial lines were collected, for an equivalent scan time of 10:00 minutes). Figs 1c and 1f were produced from a single 792 view data set with alternating diffusion directions throughout the scan. The equivalent scan time was 3:20 minutes. Major structures such as the splenium of the corpus callosum and optic radiation, and minor structures such as the anterior projections of white matter tracts in the frontal lobe and the transverse tracts of the temporal lobe can be easily delineated in all maps. Although many anisotropic structures are readily visible in these maps, due to the SNR decrease, small structures are not well defined in Fig 1c. All the maps were reconstructed at 1 mm^2 in plane resolution. The reduced datasets have been reconstructed at high in-plane resolution for demonstration purposes, but could be reconstructed at lower in-plane resolution, to be more consistent with the amount of data collected.

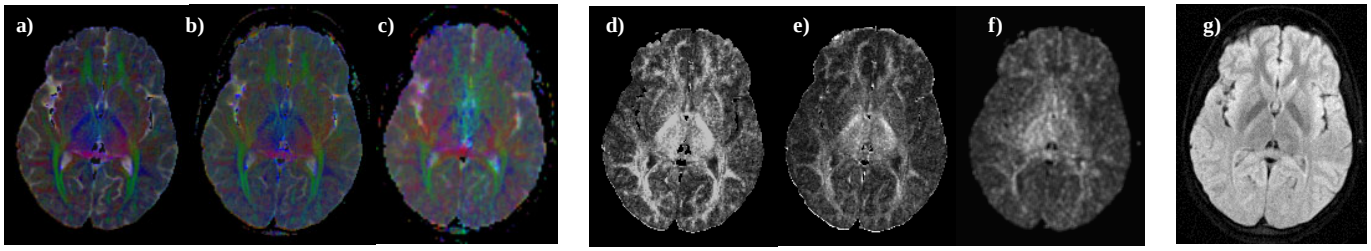

Fig 1. a-c) Colorized eigenvector maps and **d-f)** relative anisotropy maps from 792 (**a,d**), 396 (**b,e**), and 132 (**c,f**) view radial DTI exams (common imaging parameters: b=1000 s/mm^2, TE_{ave} =110 ms, TR=1500 ms, ETL=6, FOV=26 cm, slices=8, thickness=5mm, in-plane resolution is 1mm^2). **g)** Isotropic diffusion (trace) image constructed from the single 792-view dataset used to reconstruct c and f.

By reconstructing the full radial data set with alternating diffusion weighting, an image can be reconstructed that is effectively equivalent to a trace diffusion image. Fig. 1g shows such an image reconstructed from the single 792 view exam used to produce Figs 1c and 1f. The image has high in-plane spatial resolution and can be used to produce high-resolution apparent diffusion coefficient (ADC) maps.

The production of diffusion anisotropy maps from partial, or sub-sampled, single acquisition radial datasets is demonstrated for the first time. With the appropriate view ordering and diffusion weighting, anisotropy and ADC maps can be created from the same, self-registered data with minimal artifacts from motion, T2 decay and/or anisotropy. This view ordering also permits T2 maps to be calculated from the same dataset. The method further allows flexibility in the number of radial lines to be acquired. Increasing the number of radial lines collected not only increases the SNR of the images, but also reduces angular aliasing. Additionally, the diffusion-weighted images used to produce anisotropy and ADC maps are insensitive to the susceptibility artifacts often seen in echo planar imaging, i.e. signal drop out and warping, and thus have excellent registration with each other and with images obtained via conventional scanning (T1 and T2). This feature makes these techniques preferable for imaging at high magnetic field strength.

References: [1] Song, *MRM*, (44), 825-832, 2000 [2] Altbach, *JMRI*, (16), 179-189, 2002 [3] Gmitro, *ISMRM*, (11), 553, 2003

Acknowledgements: This work supported by NIH grant R21 AG021624.