Multiple Coils for Regridding Multi-Shot EPI Diffusion Data

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Introduction

A single shot EPI readout is commonly used in diffusion weighted imaging. The restricted echo train length limits resolution and the small bandwidth in the phase encode direction leads to susceptibility artefacts, especially at high magnetic field strengths. Multiple coils have been used with parallel imaging techniques to omit phase encode lines and reduce these problems [1] but the scope for further improvements using this method is limited because parallel imaging cannot achieve speed-up factors beyond the order of 2-3 without significant noise enhancement.

Multi-shot EPI readouts allow significant enhancements in resolution or reduced susceptibility artefacts. Motion during the diffusion sensitisation period causes phase changes and shifts of k-space. When data from multiple shots are combined, these effects need to be corrected and the corrections can be determined from navigator data [2,3]. The k-space shifts result in irregularly sampled data that has to be regridded. In parallel imaging, multiple coils enable the “jumping” of missing phase encodes and this works looks at the use of multiple coils to help in the regridding of irregularly sampled diffusion data.

Method

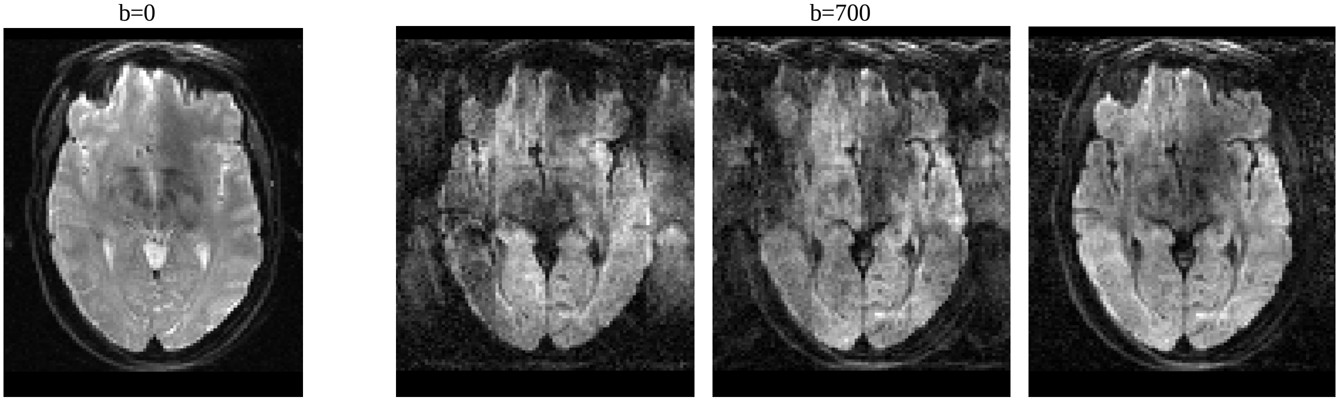
A navigated multi-shot diffusion weighted sequence was implemented on a Philips Intera 3T. The segmented EPI readout was followed by a 2D navigator mapping the centre of k-space. Data were acquired from a 6-element head coil, no cardiac gating, 4 repeats of the diffusion weighted (b=700) images, phase encode left-right, 15 readouts for each of 6 segments, acquisition matrix 90x128, TE/TR 59/1500 ms, slice thickness 4mm, segments rejected when the navigator intensity is less than 80% of the maximum. Coil sensitivity profiles were determined from the b=0 images, which are free of motion artefact, and the sum-of-squares used as the reference. A volunteer was imaged twice with all parameters identical except that in the second scan, the coil mode was switched from multi-coil to quadrature, in which case we collect data as though there were a single coil.

Using information from the navigator to determine actual sample locations, the data was regridded row-by-row by solving for **R** the matrix equation **S**=**CR** where **S** is the irregularly sampled k-space and **C** is a convolution matrix. With one coil, **C** amounts to a sinc regridding. With multiple coils, **C** is composed of cyclic repetitions of the k-space of the coil sensitivities. The cyclic shifts are irregular and correspond to the irregular sampling.

Results and Conclusion

A reconstruction from the multi-coil data was compared with i) a reconstruction using the same data, but the coil data combined to simulate one coil, and ii) data from the same coil in quadrature-mode. In case i) the data rejections and shifts are identical to the multi-coil data and in ii) the rejection rate is similar. In all data sets the rejection was worse when the diffusion direction was [1,0,1] ([FE, PE, slice]) and amounted to rejection of approximately half the data. Fig. 1 shows diffusion weighted images for one slice with this diffusion direction. Note the use of multiple coils helps in the image regridding to reduce ghosting. It was also observed that the condition number of **C** was always lower when the coil sensitivity information was used.

b=0 b=700



b=0 (multi-coil) | quadrature-mode | single coil simulated from multi-coil data | multi-coil reconstruction using coil sensitivities

Using coil sensitivity information enables k-space regions lacking data to be regridded more effectively leading to improved multi-shot diffusion weighted images.

References: [1] Bammer R. et al. Mag. Res. Med. 2002;48:128-136. [2] Atkinson D. et al. Mag. Res. Med. 2000;44:101-109. [3] Miller K. et al. Mag. Res. Med. 2003;50:343-353.

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