

Noise Bias Reduction and Parallel Imaging for the Measurement of Diffusion Decay

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Introduction

The presence of an important magnitude noise bias is known to have very detrimental effects on diffusion measurements in general [1], and in particular on the estimation of diffusion decay. Over the last years, different correction approaches were proposed to reduce or eliminate the influence of the noise bias [2], [3], [4]. A recent signal combination method was shown to significantly improve the accuracy of the estimates of several diffusion tensor imaging (DTI) parameters in the presence of an important noise bias [5]. The present work studies the application of this correction method for the estimation of bi-exponential diffusion decay parameters. Furthermore, as parallel imaging appears as a very interesting alternative to reduce both scan time and artefacts in diffusion experiments [6], the extension of the method to GRAPPA parallel reconstruction is evaluated.

Methods

An *in vivo* diffusion data set of a healthy volunteer's brain was acquired for 17 equidistant b values from 0 s/mm^2 to 4000 s/mm^2 and 3 orthogonal diffusion directions. The measurements were repeated 25 times for b values lower than 2000 s/mm^2 and 50 times for b values of 2000 s/mm^2 and higher. A diffusion-weighted single-shot EPI sequence was used with both a standard (unaccelerated) reconstruction and a GRAPPA reconstruction with an acceleration factor of 2. A commercial 12-channel head coil was used for all measurements.

All images were reconstructed using both a standard sum-of-squares (SoS) combination and the alternative algorithm (SUPER-D) proposed in [5]. This method makes use of an improved combination of signals from the array coil and complex averaging to reduce the noise bias. To act as a reference, the standard SoS images were also corrected using the statistical method (DHS) proposed in [4], which was extended to take into account the noisy signal distribution of SoS images.

The corrected diffusion decay curves were fitted to a bi-exponential model. The estimated diffusion parameters were then employed to generate synthetic diffusion images, having the same signal-to-noise ratio as the *in vivo* images, to allow a better estimation of the precision and accuracy of the different noise bias corrections.

Results and Discussion

Fig. 1 presents the *in vivo* diffusion decay curves obtained for both standard and GRAPPA reconstructions, for a region-of-interest in the body of corpus callosum. For the standard reconstruction, the SUPER-D and DHS methods lead to very similar results. However, significant differences appear between the two approaches when a GRAPPA reconstruction is used.

Fig. 2 illustrates the results obtained from the synthetic diffusion data sets. For the standard reconstruction, the SUPER-D and DHS methods allow a correct estimate of the true diffusion decay. In the case of the GRAPPA reconstruction, the SUPER-D method also gives an accurate estimation of the true diffusion signal. However, the accuracy of the DHS method suffers from the fact that the statistical distribution of the signal in GRAPPA images depends on both the coils geometry and the imaged object. Particularly, the DHS approach makes the hypothesis of spatially homogenous noise, which hypothesis does not generally hold for parallel imaging. The accuracy and precision of the two correction methods can be assessed from the simulation results presented in Tab. 1.

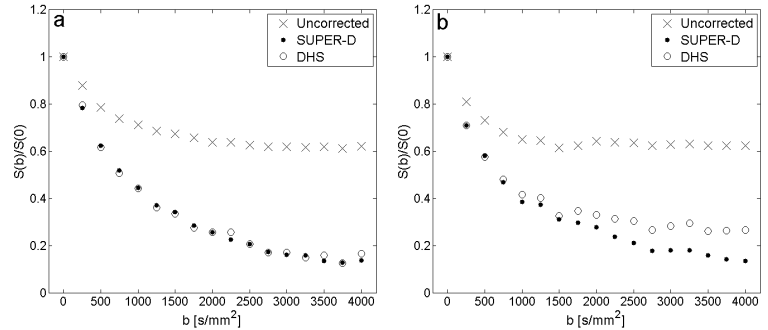


Figure 1: *In vivo* diffusion decay. a) Standard reconstruction b) GRAPPA

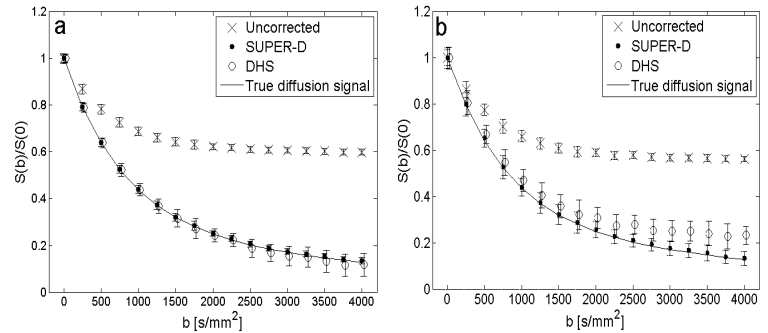


Figure 2: Simulated diffusion decay. a) Standard reconstruction b) GRAPPA

| Correction | Bi-exponential parameter | Reconstruction | |
|-------------|--|-----------------|-----------------|
| | | Standard | GRAPPA |
| DHS [4] | f_1 | 0.70 ± 0.09 | 0.64 ± 0.05 |
| | D_1 ($\times 10^{-3} \text{ mm}^2/\text{s}$) | 1.2 ± 0.4 | 1.2 ± 0.2 |
| | D_2 ($\times 10^{-4} \text{ mm}^2/\text{s}$) | 2.8 ± 0.9 | 1.7 ± 0.2 |
| SUPER-D [5] | f_1 | 0.68 ± 0.02 | 0.68 ± 0.05 |
| | D_1 ($\times 10^{-3} \text{ mm}^2/\text{s}$) | 1.30 ± 0.09 | 1.3 ± 0.2 |
| | D_2 ($\times 10^{-4} \text{ mm}^2/\text{s}$) | 2.3 ± 0.2 | 2.3 ± 0.3 |

Table 1: Fitted diffusion parameters obtained from numerical simulations. Simulated parameters: $f_1 = 0.69$, $D_1 = 1.28 \times 10^{-3} \text{ mm}^2/\text{s}$, $D_2 = 2.30 \times 10^{-4} \text{ mm}^2/\text{s}$.

and GRAPPA reconstructions. While other correction algorithms were developed for standard imaging, the SUPER-D method appears to provide a distinctive opportunity when GRAPPA parallel imaging is used.

References

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