Discarded image volumes and gradient table alignment: how much do they affect DTI tensor calculations?

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Introduction:

Several preprocessing steps are applied to raw DTI image sets prior to the calculation of tensor model parameters. Before the preprocessing steps, it is a common practice to discard some of the diffusion weighted image (DWI) volumes (or slices) if there are artifacts. After the bad volumes are discarded, the second step is to apply spatial transformations to align all DWI and non-DWI images. This corrects both the image deformations due to eddy current effects and the rigid head motions. Some researchers apply the same motion corrections to the gradient tables to ensure that the gradient direction is applied accurately to individual DWI volumes. This may be necessary for large motions but its efficacy is questionable for minor head motions. In this study, we investigated the impact of these steps on the FA maps, which are the most commonly used DTI parameter maps.

Methods:

The subjects were scanned using a 3T Philips Achieva system (Best, Netherlands). The study was approved by the IRB of the university and written consents were obtained from the subjects. DTI data were acquired using a SE-EPI pulse sequence with 32 non-collinear gradient directions with b=800 and a single acquisition with b=0. 60 axial slices were collected to cover the whole brain with FOV=224*224mm^2 and 1.75*1.75*2mm^3 voxel size, NEX=1. TR=9290ms and TE=55ms were used with SENSE=2.4.

To investigate the impact of eliminating bad DWI volumes on FA data quality, a data set with no artifacts was chosen. The first FA map is generated from the full data set. Then, randomly chosen DWI volumes from the set were discarded one by one and a separate FA map was generated every time. The quality of an FA map obtained from a reduced data set was compared against the FA map from the full set by subtracting the corresponding FA maps. Mean and standard deviation of these difference images were calculated and plotted in Fig.1. Fig.2 illustrates the error image overlaid onto the FA map. The error image was calculated by subtracting the FA map obtained after 7 discarded volumes from the FA map obtained from the full DTI data set. The error image was thresholded at 0.05 to highlight areas where the errors were the highest.

The impact of gradient table correction for motion was investigated by repeating the tensor model fitting to DTI data sets twice; the first with the original gradient table, the second with the motion-corrected gradient table. Motion and eddy current distortion correction as well as gradient table correction were done using CATNAP software [1]. Tensor fitting was done using DTIStudio software [2] because CATNAP did not allow tensor fitting without table correction. Using an approach similar to the previous section, FA error images were obtained by subtracting FA maps calculated with and without gradient table correction. DTI data from 5 subjects were used and none of the data sets had any rigid head motion larger than 2mm in any orthogonal direction. Besides, those data did not have any artifacts, so no DWI volumes were discarded for tensor calculations. The histogram of the FA error image calculated from the data of subject 1 is shown in Fig.3. Table 1 summarizes the means and standard deviations calculated from the error images obtained from the five different subjects' data.

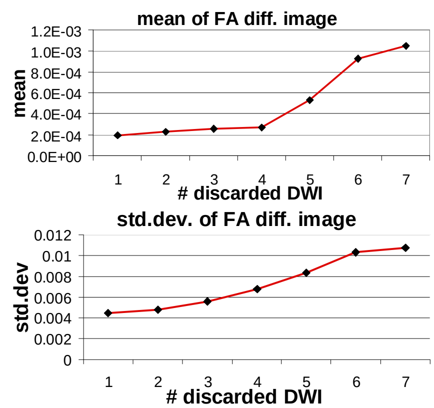
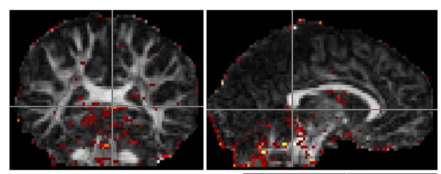


Fig.1. Plot of mean (top) and standard deviation (bottom) of the FA error (difference) images as the number of discarded DWI volumes increases.

Results and discussion:

It can be seen from Fig.1 that major degradation in the quality of the FA maps was not observed up to four volume eliminations. On the other hand, Fig.2 demonstrates that the errors were not distributed uniformly and the largest errors were in high diffusion areas such as CSF. This could be expected since the DWI pixels will have lower SNR in high diffusion areas. Hence, those pixels will be more sensitive to errors when the number of measurements was reduced by eliminating images from DTI tensor calculations. On the other hand, no major errors were observed in FA maps when the gradient tables were not corrected for motion. The means and standard deviations of these FA error images were several orders of magnitude smaller than the typical FA values seen in cerebral white matter fiber tracts (typical FA > 0.15~0.20). In cases where FA maps are statistically compared between two groups, between-subject variability will also be much larger than these errors. Gradient table correction could be important if the head motion is much larger than a few mm. But in most DTI studies, the head of the subject is fixed using tight padding and the subjects are mostly cooperative. Therefore, gradient table correction may not be essential for the majority of DTI studies.



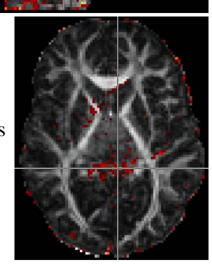


Fig.2. FA error image overlaid in color onto an FA map. The error image was obtained by taking the difference of FA maps with no volume and 7 volumes discarded. Note that the errors were not distributed uniformly.

References:

[1] B. A. Landman, *et al*. NeuroImage. 36:1123-1138 (2007).

[2] Jiang H., *et al*. Comp. Meth. and Programs in Biomed. 81:106–116 (2006).

	Error images	
	mean	Std. dev
Subj.1	-1.9E-6	1.6E-4
Subj.2	1.3E-4	8.7E-4
Subj.3	-8.7E-5	6.5E-4
Subj.4	-8.6E-5	4.8E-4
Subj.5	2.8E-5	3.8E-4

Table 1. Mean and standard deviation in error images that were obtained by subtracting FA maps with and without gradient table correction.

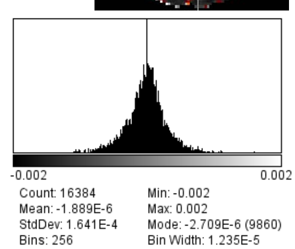


Fig.3. Histogram of the error image. It can be observed that the errors are normally distributed.