Dealing with Artifacts Induced by Spike Noise in Diffusion Tensor Imaging

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Introduction: Diffusion Tensor Imaging (DTI) is sensitive to motion, cardiac pulsation, susceptibility variations and system instabilities. We identified artifacts caused by severe spike noise in one of our datasets, and investigated their effect on DTI-derived parameters such as Fractional Anisotropy (FA). We apply the RESTORE algorithm for estimation of the diffusion tensor with outlier rejection, and compare the outcome to manual exclusion of affected slices.

Methods: The subject under investigation was scanned on a 1.5T MRI scanner with a pulsed-gradient single shot spin echo echo-planar imaging (EPI) sequence with cardiac gating (TR=20, RR≅20s), TE=85ms, 61 distributed directions interleaved with 7 non-diffusion weighted b≅0 acquisitions, maximum b factor=1200smm^{-2}, matrix size=96×96, FOV=220mm, image resolution=2.3mm^3 reconstructed to 1.8×1.8×2.3mm^3. The diffusion tensor (DT) was estimated firstly using a standard least squares regression model[1]. The RESTORE algorithm[2,3] was then used to estimate the tensor with automatic outlier rejection. Finally, artifacts in the diffusion data were manually labeled as outliers (with a large negative value) before tensor estimation using RESTORE. FA maps were calculated from the diffusion tensors generated by each method (FA_{st}, FA_{res}, FA_{man} respectively). Maps of FA_{res} were compared with FA_{st} to evaluate the effect of RESTORE. Similarly, FA_{man} and FA_{res} were compared to identify the effect of manually removing the spike artifacts compared to using RESTORE. To assess the validity of excluding data from the tensor estimation, an image was labeled as outlier in a dataset free from spike noise artifacts. The FA map derived from this modified data set, FA_{val}, was then compared with FA_{res}.

Results: Figure 1 shows a typical image affected by spike noise. This was the only affected image out of the 68 diffusion-weighted images acquired at this slice position. It also shows the corresponding FA_{st} map calculated from the original data, where it is impossible to visually detect any artifact.
These spike noise related artifacts were not identified by RESTORE when using a standard deviation estimate calculated from the background noise of the data. In fact, as shown in figure 2 the absolute change (a) and the percentage change (b) in the FA values, calculated comparing FA_{res} and FA_{man}, are characterized by an intensity modulation that reflects the underlying artifact. This modulation of FA_{res} exhibits a change of the order of 5% within adjacent areas belonging to the same white matter tract (white arrow in figure 2 (b)) that are not appreciated by the naked eye. When eliminating one of 68 images from the optimized acquisition scheme, though, we introduce a bias in FA, as shown in figure 3, where the absolute (a) and percentage (b) change in FA values is calculated between FA_{res} and FA_{val} for a slice free from spike noise related artifacts. A similar range of percentage change in FA of white matter are detected in this latter case, although this change is overall more uniform as shown in figure 3 (b). For clarity, we thresholded FA>0.3 to show mainly white matter tracts (figure 2 (b) and 3 (b)), but changes of similar or even higher values were present also in grey matter regions.

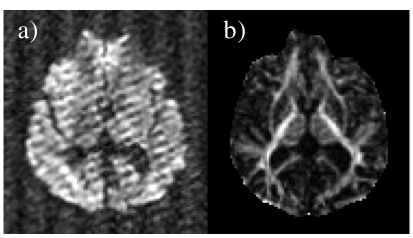

Figure 1. Spike noise artifact and FA map

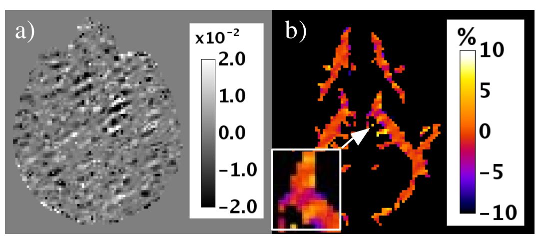

Figure 2. Manual exclusion of spike noise artifact

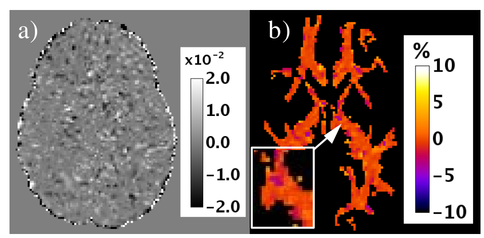

Figure 3. Exclusion of artifact-free slice

Discussion and Conclusions: We have shown how a single image affected by spike noise, out of 68 distributed diffusion-weighted images, can introduce fluctuation in the FA value along white matter tracts of the order of changes induced by pathology. A combination of manual editing and RESTORE allowed us to remove the artifact from the data. We have also shown that the effect of removing an image from the acquired dataset consists of a change in FA itself, although more homogeneously throughout white matter. Further investigation is needed to establish whether RESTORE could be optimized to detect artifacts producing changes such those introduced by spikes.

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