Improving Diffusion Tensor Fiber Tracking by Acquiring Additional FLAIR EPI Data to Eliminate CSF Contamination

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Introduction

FLAIR is an important technique to eliminate cerebrospinal fluid partial volume effect. Previous researches indicated FLAIR DTI could improve tractography results compared with conventional DTI in the region near ventricle [1] and in limbic system [2]. However, the reduced SNR due to FLAIR preparation may affect detected tractography accuracy. Furthermore, the scan time for FLAIR DTI is about twice of that for conventional DTI, which increases the likelihood of motion artifact particularly in clinical applications. Therefore, in this study we try to combine conventional DTI and FLAIR EPI (combined DTI) to get the benefits of better SNR and elimination of CSF contamination in clinical acceptable time.

Material and Methods

The motivation of this study is to minimize the partial volume effect of CSF in diffusion tensor fiber tracking. While CSF partial volume effect is significant in low-b images, it can be neglected in high-b DWI. Therefore, we proposed the combination of FLAIR EPI as b0 image, with substantially suppressed CSF partial volume effect, and DWI of conventional DTI as high-b image for tensor calculation. The inconsistency of signal level between FLAIR EPI and conventional DTI is taken care of by referring to white matter (WM) signal on b0 image in both conventional DTI and FLAIR EPI, followed up automatic adjustment before the calculation of combined DTI. Data sets were acquired from five healthy volunteers (aged 22-36 years old) using a 3T MR system (Philips Achieva), with an eight-channel circularly symmetric head array coil. Scan time for conventional DTI (NEX=4, b=0&1000) was 2m14s and the additional FLAIR EPI (NEX=6, b=0, TI=2200ms) took an extra 1m36s, making total scan time for combined DTI to be 3m50s. For comparison, FLAIR DTI (NEX=4, b=0&1000, TI=2200ms) was also acquired in 6m14s. Three DTI modalities (including FLAIR DTI, conventional DTI and FLAIR EPI) were repeated for five times on each subject for statistical comparison. EZ-tracing [3] was used for global tracing, with threshold settings of FA > 0.2 and turning angle < 18˚.

Results

Figure 1 shows tracing results of conventional DTI (a), FLAIR DTI (b) and combined DTI (c), as well as their corresponding vector-encoded FA maps (d) to (f) (red rectangle region in (a) to (c)). The resulting fiber tracts in yellow color were superimposed on EPI images with b=0. In both Figs. 1(b) and 1(c), more tracts were found in para-ventricular regions, demonstrating the elimination of CSF contamination. In addition, FA as well as fiber direction consistency of combined DTI in Fig. 1(f) are higher than those in Figs. 1(d) and 1(e) within the encircled region. Figure 2 shows the statistical comparison among 5 subjects. The number of traced voxels in combined DTI is more than in conventional DTI, with statistic significance in both individual test (P<0.004, paired Student t test; n=5) and group test (P<0.0005, paired Student t test; n=5). On average of 25 data sets, traced voxels in combined DTI are 16.74% more than in conventional DTI and 6.53% more than in FLAIR DTI, indicating superior performance of combined DTI among three methods.

Discussions

From our results, combined DTI technique is also capable of suppressing CSF partial volume effect as well as FLAIR DTI technique. Since combined DTI uses non-FLAIR-prepared DWI as high-b images whose SNR is higher than FLAIR-prepared DWI in FLAIR DTI, the calculated FA and fiber directions are more accurate and reliable, hence resulting in more traced voxels (about 6.53%). Moreover, although the combined DTI takes a little bit longer scan time than conventional DTI (2m14s vs 3m50s), the scan time of combined DTI is shorter than FLAIR DTI (3m50s vs 6m14s), saving about 26% acquisition time. A minor pitfall of this technique is that since the FLAIR EPI images used in combined DTI were adjusted by referring to WM of b0 image of conventional DTI, the signal levels of gray matter in FLAIR and conventional DTI are inconsistent. As a result, the ADC values of gray matter in combined DTI become underestimated, even if the calculated FA value remains the same as well as tracing results.

Conclusions

The combined DTI improves white matter tractography by eliminating CSF partial volume effect. It has the advantage of higher SNR and shorter scan time as compared with FLAIR DTI. Therefore, we conclude that combined DTI is suitable for clinical applications for fiber tractography where gray matter ADC is relatively unimportant.

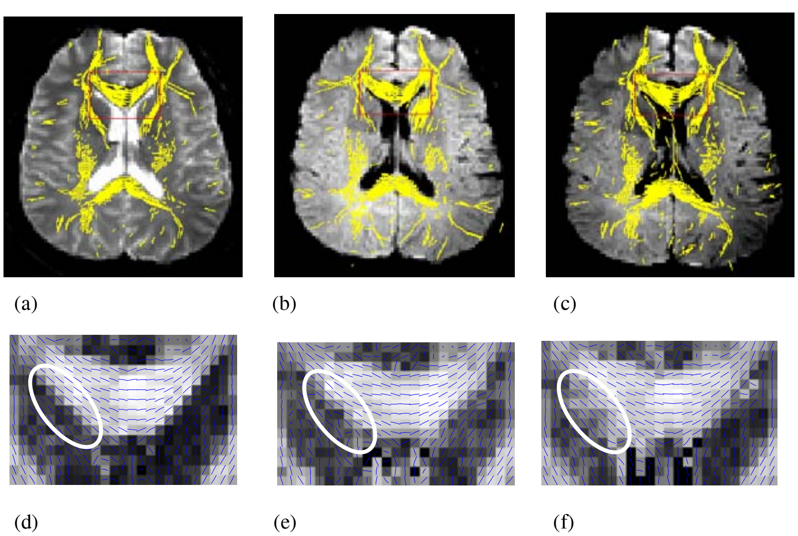

Figure 1 Comparison of tractogram and vector FA-encoded maps among conventional DTI (a,d), FLAIR DTI (b,e) and combined DTI (c,f).

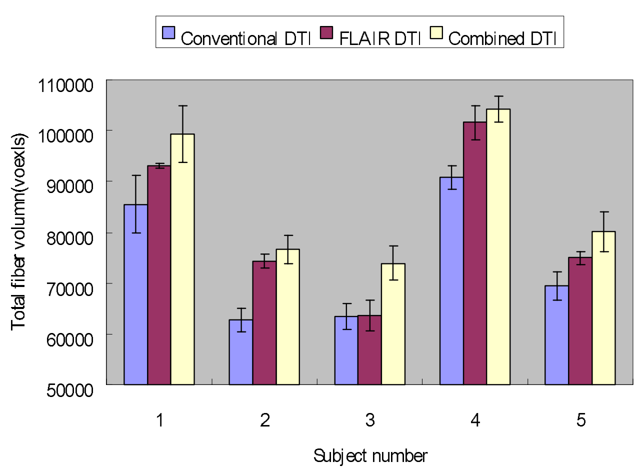

Figure 2 Comparison of total fiber tracking voxels among conventional DTI, FLAIR DTI and combined DTI.

References

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