Effects of Directional Resolution in diffusion tensor tractography: comparisons on total fiber volume and fiber consistency

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Introduction

Diffusion tensor imaging (DTI) is used to study white matter composition and architecture *in vivo*. To increase the signal to noise ratio (SNR) of DTI data, studies typically use repeated acquisitions of the same set of diffusion weighting (DW) directions, or use increased DW directions sampled from the q-space with higher directional resolutions. Simulation-based studies have sought to optimize DTI acquisitions and suggest that increasing the directional resolution of a DTI dataset (i.e., the number of distinct directions) is preferable to repeated signal averages of fewer DW directions, in an equal scan time comparison. The characterization of how the number of DW directions impacts the DTI precision and accuracy was performed in previous studies in terms of *in vivo* DTI indices such as the fractional anisotropy (FA), mean diffusivity (MD), and principal eigenvector (PEV) findings [1]. In this study, we further compare the effects of directional resolution on DTI by examining the total fiber volume and fiber consistency obtained from tractography results.

Material and Methods

Data sets were acquired from a healthy volunteer aged 36 years old using a 3T MR system (Philips Achieva, Nederland), with an eight-channel circularly symmetric head array coil. DTI data were acquired separately using direction resolutions of 6, 15, and 32 at NEX of 5, 2 and 1, respectively, keeping the scan time almost the same. The rest of scan parameters were as follows: b=0&1000, TE=65ms, TR=4000ms, matrix size = 128x128, slice thickness = 5mm, number of slices = 20. Three DTI datasets (including 6, 15, and 32 directional DTI) were repeated five times for statistical comparison. EZ-tracing [2] was used for global tracing, with threshold settings of FA > 0.2 and turning angle < 18˚. The definition of total traced volume (voxels) is the number of voxels successfully traced as fiber bundles. Fiber consistency is defined as the correlation coefficient of three-dimensional fiber probability distributions between any two DTI datasets from the same subject. The mean and standard deviation of ten fiber consistency values among five DTI datasets were calculated to represent the reproducibility of fiber tractography.

Results

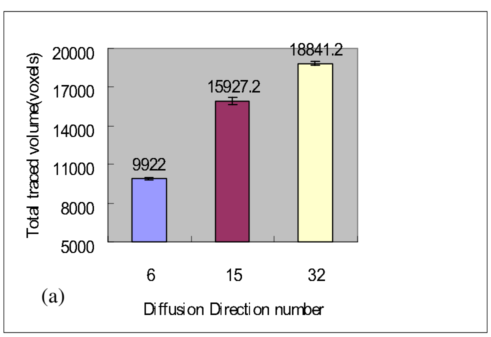
Figure 1(a) shows the total traced volume (voxels) calculated from 6 directional DTI (NEX=5), 15 directional DTI (NEX=2), and 32 directional DTI (NEX=1). In the results, we found that the traced fiber volume of the 15 directional DTI is 60.5% larger than that of the 6 directional DTI, and that for the 32 directional DTI is 89.9% larger than that of the 6 directional DTI. Figure 1(b) shows the mean and standard deviation of fiber consistency values of 6 directional DTI (NEX=5), 15 directional DTI (NEX=2), and 32 directional DTI (NEX=1). Similar to traced fiber volume, the fiber consistency value in 15 directional DTI data is higher than that in 6 directional DTI, and fiber consistency value of 32 directional DTI is higher than that of 15 directional DTI. Figure 2 shows the comparison of fiber tracking from one slice out of the three directional volume DTI data: (a) 6 directional DTI (NEX=5), (b) 15 directional DTI (NEX=2), and (c) 32 directional DTI (NEX=1), in which the traced fibers in 32 directional DTI show more successful tracking than 15 directional DTI and 6 directional DTI, as indicated in red rectangular region.

Discussion

Although 32 directional DTI has the lowest SNR in single original images, it has highest directional resolution for diffusion tensor calculation. From our current results, the directional resolution seems to be more important than image SNR in terms of traced fiber volume and fiber consistency, suggesting that higher angular resolution is more helpful than increasing image SNR in fiber tractography under the same acquisition time. Since our current investigation used the manufacturer's default settings for DW directions, the findings from our study reflect simply the usual clinical conditions, with the detailed effect of different distributions of DW directions (sampled from the q-sphere at the same directional resolution) remaining to be further studied.

Conclusions

Our results showed that the increase of diffusion directions in DTI not only impacts the precision and accuracy of *in vivo* fractional anisotropy (FA), mean diffusivity (MD), and principal eigenvector (PEV), as documented in a previous report [1], but also improves the diffusion tensor tractography results.



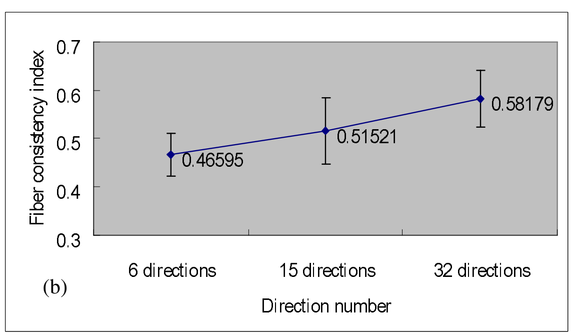


Figure 1
(a) Comparison of total traced volume (voxels) among 6 directional DTI (NEX=5), 15 directional DTI (NEX=2), 32 directional DTI (NEX=1)
(b) Comparison of fiber consistency index among 6 directional DTI (NEX=5), 15 directional DTI (NEX=2), 32 directional DTI (NEX=1).

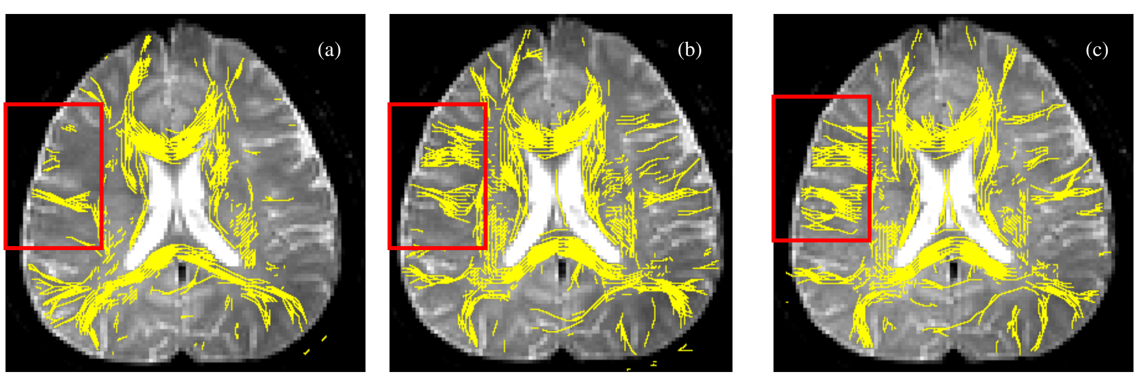


Figure 2
Comparison of the fiber tracking results among three modalities:
6 directional DTI (NEX=5)(a)
15 directional DTI (NEX=2)(b)
32 directional DTI (NEX=1)(c).

References

[1] Bennett A. Landman, et al. *NeuroImage*,36:1123-1138 (2007).
[2] Terajima K, et al. *J Neuroscience Methods*, 116:147-155 (2002).