Higher anisotropy in Diffusion Spectrum Imaging at longer diffusion times

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Target audience Scientists and clinicians interested in Diffusion Spectrum MRI and its methodological development

Purpose To demonstrate that Diffusion Spectrum Imaging at longer diffusion times gives rise to higher anisotropy measures, as illustrated by using a stimulated echo sequence in a clinical scanner *in vivo*.

Diffusion Spectrum MRI (DSI) [1] has become a powerful tool for non-invasive imaging of the brain tract architecture [2,3]. In DSI, the difference in water mobility between the orthogonal and longitudinal directions of the fiber bundles can be emphasized by increasing the diffusion time [4,5]. Hence, higher diffusion times lead to an increased anisotropy and better fiber tracking [6].

In conventional spin-echo-based diffusion sequences, longer diffusion times are prohibitive due to the concomitant decrease in SNR. In this abstract we utilize a stimulated echo sequence *in vivo* to illustrate the increased quantitative anisotropy (QA) at longer diffusion times.

Methods For the DSI acquisitions, q-space was sampled using a twice-refocused spin echo (SE) and a stimulated spin echo (STIM [7]) sequence. In both sequences a recently proposed radial q-space sampling scheme [8,9] was used. The radial sampling scheme acquires several q-space samples (e.g. 4) along a number of radial lines (e.g. 59). This has the advantage that every radial line acquired in q-space is directly connected to a value of the radial ODF at the same angular location in the spatial domain by the Fourier slice theorem [8].

In vivo brain data of healthy volunteers were acquired on a 3T scanner (Skyra, Siemens, Erlangen) using a 32-channel head coil (b_{max}=4000, TR = 4000, 2.3×2.3×5 mm resolution, 10 slices, multiband acceleration of 2 [10], SE: TE = 113ms, STIM: TE = 180, 256, 360ms) in a single scan session. For the radial DSI q-space sampling, 236 samples were acquired arranged on 59 radial lines, evenly distributed on a radius 4 half sphere. Reconstruction was performed offline using custom-made software (Matlab, Mathworks) and displayed using Matlab and DSI Studio [11]. DSI datasets were compared with the normalized RMSE (NRMSE) and the Jensen-Shannon Divergence (JSD) [12] of the Orientation Distribution Functions (ODFs) relative to the ODFs of the SE DSI dataset.

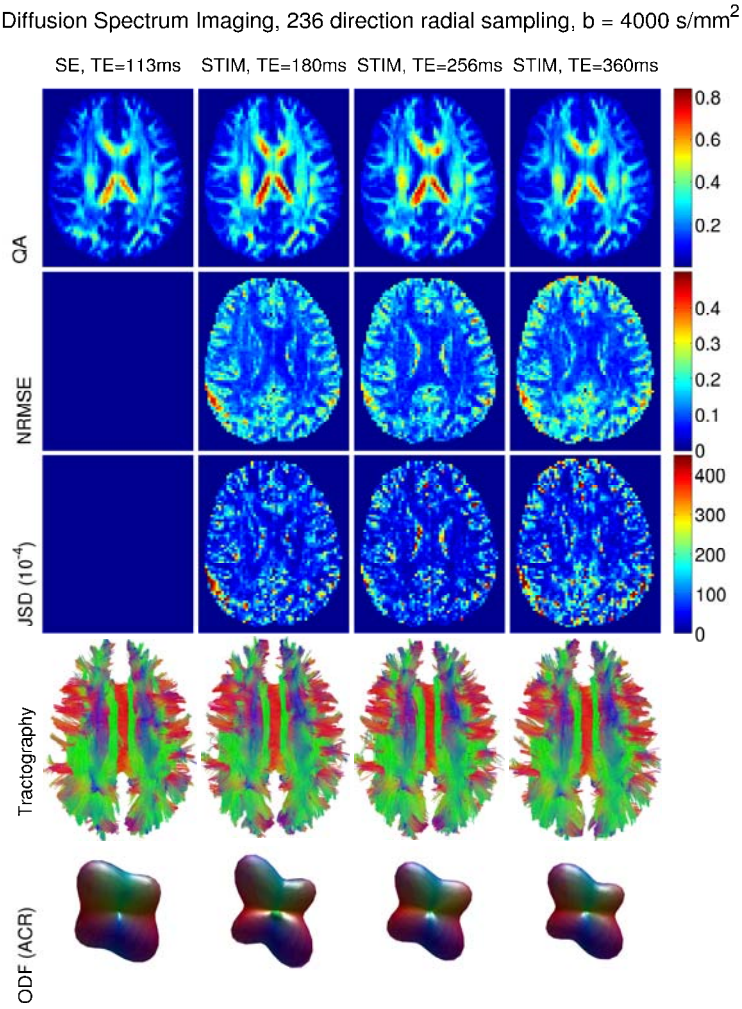

Fig. 1 Radial DSI reconstructions of a human brain volunteer acquired using a twice refocused spin echo (SE) and a stimulated spin echo (STIM) sequence. Shown are the quantitative anisotropy [13] (QA) of the prominent fiber orientation, the normalized RMSE error of the ODF (NRMSE) and the Jensen-Shannon divergence [12] (JSD) of the ODF relative to the spin echo measurement, tractography results of the central 10 slices and single ODFs selected from the Anterior Region of the Corona Radiata (ACR).

Results and Discussion Figure 1 compares the radial DSI reconstruction results of datasets acquired with SE and STIM sequences, whilst Table 1 lists QA values in the Corpus Callosum and SNR in the raw diffusion weighted images. At longer diffusion times the QA is higher when measured with STIM. At the longest diffusion time (STIM TE 360ms), this effect is somewhat tempered by the lower SNR. The higher QA at longer diffusion times can also be assessed from the sharper ODFs. For all STIM results, the NRMSE and JSD are low, except for the artifact in the posterior part of the brain arising from the multiband acquisition. Notwithstanding the longer echo times, the STIM datasets retain sufficient SNR to perform DSI reconstruction, showing that a stimulated echo sequence is a valuable option for DSI. Indeed, the increased anisotropy (Table 1) suggests that stimulated echo sequences might outperform spin echo sequences.

Table 1 Quantitative Anisotropy (QA) of the Corpus Callosum and SNR of the raw diffusion weighted images (b=1470) of the datasets in Fig. 1.

	TE (ms)	QA	SNR
SE	113	0.57±0.05	78.3
STIM	180	0.67±0.08	64.4
	256	0.66±0.05	64.2
	360	0.59±0.08	58.9

Conclusion DSI datasets acquired at longer diffusion times show increased anisotropy. To counter the loss in SNR at longer diffusion times, a stimulated echo sequence can be used as shown here. The higher anisotropy in DSI datasets, resulting from longer diffusion times, could be of great benefit during fiber tracking experiments.

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