



Halving Imaging Time of Whole Brain Diffusion Spectrum Imaging (DSI) Using Simultaneous Echo Refocusing (SER) EPI

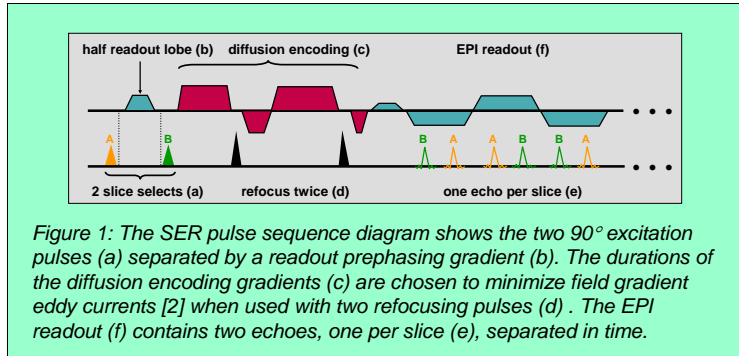
Timothy G. Reese*, Thomas Benner*, Ruopeng Wang*, David A. Feinberg† and Van J. Wedeen*

*Athinoula A. Martinos Center For Biomedical Imaging,

Massachusetts General Hospital and the Harvard Medical School, Boston, MA USA

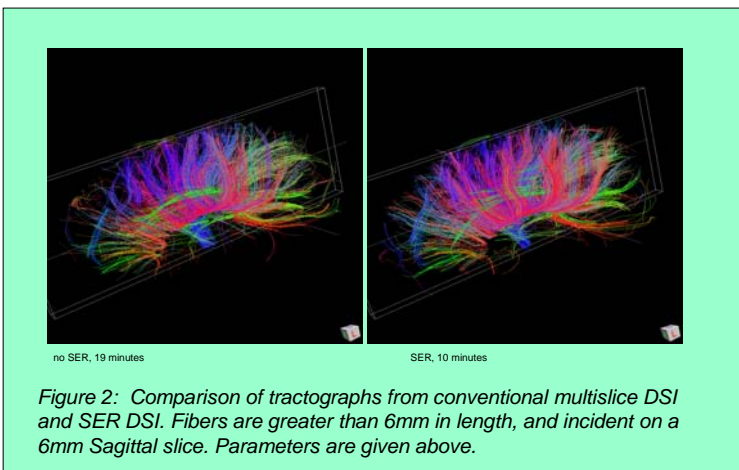
†Advanced MRI Technologies, Sebastapol, CA USA

DSI of the brain promises the visualization of neural connectivity previously unattainable by noninvasive means [1]. Previously, DSI has been limited to research use by its long scan times, both due to the need for hundreds of different diffusion encoding axes, and the need for full brain coverage of the imaged volume. Here we present a method for reducing the total scan time by nearly one-half to a clinically reasonable 10 minutes.



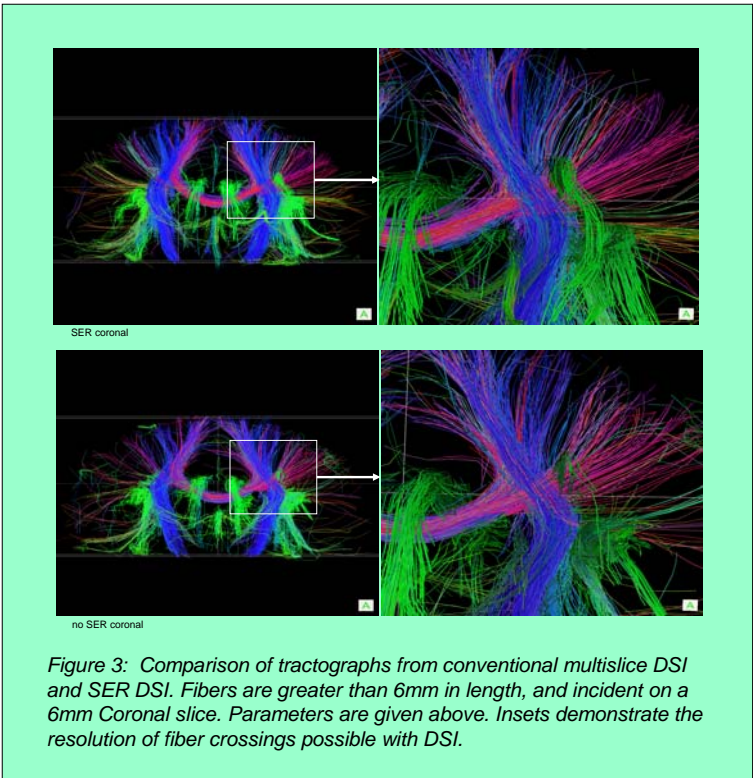
Methods and Results: The present study uses the SER method [3] to double the number of images acquired in a single echo planar (EP) excitation. SER time-multiplexes the signal from two adjacent and nearly simultaneous slices in a single EP readout. As shown in figure 1, the excitation of the two slices is separated by an encoding gradient that places the corresponding echoes at different locations in spatial-frequency space (k-space). When the data is reconstructed, each half of the k-space data is transformed into a complete image. Since each diffusion encoding generates two slices, this provides a data acquisition rate of nearly twice that of a conventional single-shot diffusion encoded EP acquisition.

Two identical studies were completed, comparing conventional single-slice EP DSI and SER EP DSI. A normal volunteer was scanned with informed consent using an established protocol. The data was collected using a Siemens TIM Trio scanner (Siemens Medical Systems, Erlangen, Germany) with a 32 channel head coil developed at the Martinos Center. The imaged volume covered the whole brain at isotropic 3.2 mm resolution, with a 64x64 image matrix. 26 conventional and 13 SER double slices were acquired, in 19 minutes and 10 minutes respectively, using 258 encoding values with a maximum $b = 8500 \text{ sec/mm}^2$. The images were reconstructed using GRAPPA [4] with an



acceleration of 2 and 32 reference lines. The SER images had a TE/TR of 150/2340ms, and without SER required a TE/TR of 145/4370ms. In both cases, the readout time was minimized according to the sampling and gradient capabilities of the scanner. Diffusion tractographs (figures 2 and 3) were produced offline from the two sets of data as described in [1].

Discussion: Comparison of the source images and tractographs from the two methods showed matching quality and detection of white matter tracts, differing only in the time required for acquisition. The SER technique significantly impacts MRI techniques like DSI which require a long encoding time compared to the total sampling time. In general, as the ratio of sampling time to encoding time of a specific technique increases, its efficiency increases. With the DSI readout time small compared to the diffusion encoding time, expanding the readout to accommodate an additional echo is practically free as a percent of total scan time; in the present example SER increases the TE by only 5 ms. The longer TE and additional readout time of SER does increase susceptibility artifact; slightly increased distortion around the frontal lobe could be detected in SER DSI source images acquired without acceleration, but the resulting tractographs were unaffected.



The difference in clinical acceptance between a 20 minute scan and a 10 minute scan is significant. A 10 minute DSI scan could be reasonably included in a routine clinical scan without great hardship to the patient or an unacceptable increase in total exam time. Additional speedup is forthcoming; using a new body-centered cubic table [5] the number of encoding steps can be reduced by 25%, reducing the present DSI SER scan time to less than 8 minutes. The SER method can be similarly advantageous to any high-b diffusion MRI. SER can be used to extend coverage or improve resolution, within the available scan time, according to specific diagnostic needs.