Improved Visualization of Iron-rich Structures in the Brain with 3D Multiecho GRE Imaging

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Introduction Deep brain stimulation within the subthalamic nucleus (STN) has been shown to be an efficient therapy for patients with Parkinson disease (1). The STN is a small lens-shaped nucleus in the brain that is a part of the basal ganglia system. Its small dimensions and anatomic characteristics make it difficult to localize on MRI. The DBS lead electrodes are usually implanted stereotactically with reference to an atlas and monitored with electrode recordings. Inter-individual variation of the STN, however, renders its precise localization difficult. In recent years there has been increasing interest in using MR imaging to guide the accurate placement of the electrodes (2). The local iron deposits in the STN have been exploited to improve its appearance on T2*-weighted images (3). A multiple-echo GRE pulse sequence (4) can be used to acquire a 3D high resolution image data set to cover the STN region. To our knowledge, the optimal method combine the information from the series of has not been determined. A good post-processing method enhances the contrast and sharpness of the STN and small veins, while not introducing substantial artifact or noise. In this study, we compared various post-processing methods to find an appropriate method to process a series of T2*-weighted echoes to visualize the STN.

Theory and Methods All the MR data sets were acquired on a 3T MR scanner (GE Signa, 14.0 M5 Excite, Milwaukee, WI) using an 8-channel phased-array head coil. A healthy volunteer was scanned under an IRB-approved protocol. A multiple-echo GRE pulse sequence was used with the following imaging parameters: FOVx = FOVy = 25cm, imaging matrix 512×384, flip angle = 30°, readout bandwidth = ± 41.67 kHz, 1 signal average (NEX), TR = 41.3 ms, 32 1.4-mm slices with zero-filled reconstruction to yield 64 images. The total imaging time was 8:30. Six gradient echoes were acquired with TE = 4.2, 10.7, … , 36.6 ms to provide T2* weighting. The six 3D data sets were transferred to local workstation for post-processing.

Eight post-processing methods were evaluated, as outlined in Table 1. All the methods were implemented using MatLab. Method 1 is the simple arithmetic mean calculated on a pixel-by-pixel basis. Method 2 calculates the root-mean- square technique, which is similar to the weighted square average method used in (4). Method 3 uses the square of the mean root. Note that method 4, 5, 6 are counterparts of method 1, 2, 3, with the only difference is that echo 1 was dropped. These methods were evaluated based on the observation that first echo might has very strong signal intensity that could dilute the T2* weighting of the later echoes. Method 7 is a T2* map, calculated with linear regression of all the echoes. Method 8 applied a Weiner filter to the results of method 1.

Table 1

Method No.	Equation/ Description	Contrast of STN	Sharpness of STN	Contrast of veins	Sharpness of veins	Noises/ Artifacts	Overall Quality	Total Score
1	$\frac{1}{5}\sum_{i=2}^{6} E_i$	3	3	4	4	3	3	20
2	$\sqrt{\frac{1}{5}\sum_{i=2}^{6} {E_i}^2}$	4	3	4	4	3	4	22
3	$\left(\frac{1}{5}\sum_{i=2}^{6} \sqrt{E_i}\right)^2$	4	3	4	4	3	4	22
4	$\frac{1}{6}\sum_{i=1}^{6} E_i$	3	3	3	3	3	3	18
5	$\sqrt{\frac{1}{6}\sum_{i=1}^{6} {E_i}^2}$	4	3	3	3	3	3	19
6	$\left(\frac{1}{6}\sum_{i=1}^{6} \sqrt{E_i}\right)^2$	4	3	3	4	3	3	20
7	T2* map	2	3	2	2	3	2	12
8	Weiner filter of Method 1	4	3	4	4	3	4	18

All the images processed by the post-processing methods were evaluated by an experienced radiologist on a display workstation (Advantage Windows; GE Medical Systems). Evaluation was performed using six different criteria includes the contrast and sharpness of STN, the contrast and sharpness of the small veins, the overall image artifacts/noises level and quality. The criteria were selected so as to test for the desired fidelity of the STN and also the veins. Each category has a score range from 1-4.

Results The scores for each method are listed in Table 1. The calculated T2* map (method 7) underperformed the other methods. Four representative images are shown in Fig 1, corresponding to methods 1, 2, 4, and 6. Dropping the first echo improved the image quality in this comparison. (If an early echo is not needed for any other purpose, the TEs of the echo in the entire echo train could be shifted later.) Both methods 2 and 3 outperformed the simple arithmetic averaging method. The application of a Weiner filter of method 8 process did not appear to improve the image quality in this test.

Discussion and Conclusion

The study investigated the differences in the post-processing options to enhance the visualization of STN and small veins in multiple-echo GRE imaging. These results indicated that root-mean-square or square-root-mean method with the exclusion of the first echo worked best.

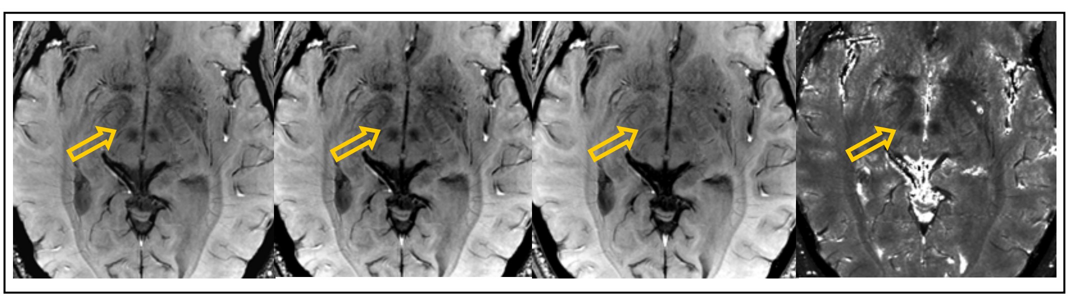

Figure 1: The axial slice that contains the STN. Resulted images from post-processing methods 1, 2, 4, 6 (from left to right).

References 1. Kumar R, et al, Neurology1998;51(3):850-855. 2. Pollo C, et al, J Neurosurg 2007;106(1):36-44. 3. Elolf E, et al, AJNR 2007;28(6):1093-1094. 4. Annamraju RB, ESMRMB 2008:482.