Improved subthalamic nucleus visualization using quantitative susceptibility imaging

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Purpose

Neurosurgeons performing deep brain stimulation procedures on Parkinson's disease patients often must pinpoint the precise location of the subthalamic nucleus (STN) in order to implant the stimulating electrode at the correct target. However, the STN can be difficult to visualize on conventional MR images such as T2* weighted (T2*W) and T2-weighted (2TW) images. Since the STN is a site of iron deposition in the brain[1], it appears hyperintense on quantitative susceptibility mapping (QSM), a recently developed MRI technique that is sensitive to the presence of iron. The purpose of this study is to test the hypothesis that QSM is better than T2*W and T2W for delineating the STN.

Materials & Methods

Ten healthy volunteers were imaged on a 3T scanner using a T2W fast spin echo sequence and a multiecho gradient echo sequence with identical spatial resolution ($0.75\times0.75\times2mm^3$, 40 coronal slices). Other imaging parameters included TE=86ms, TR=8s, bandwidth=±62.5Hz, number of averaging=4 for T2WI, and 11 TEs evenly spaced between 4ms and 40ms, TR = 45ms, bandwidth=±62.5Hz, flip angle=15º, number of averaging=1 for the gradient echo sequence. The scan time was under 5 minutes for both acquisitions. From the gradient echo sequence, a T2*WI was taken from the 6th echo (TE=25ms), and a QSM was reconstructed from all the echoes utilizing a morphology enabled dipole inversion (MEDI) approach [2]. The contrast-to-noise ratio (CNR) of the STN in the QSM, T2*W, and T2W images for each subject was measured using a 1D signal intensity plot through the STN. The peak voxel value of the STN minus the minimum voxel value of the neighboring background was taken as the contrast. Noise was measured by calculating the standard deviation of the signal intensity from a region of interest in the neighboring background, the thalamic region.

A paired t-test was performed on the STN CNRs to assess the difference between QSM and T2*W, and between QSM and T2W.

A radiologist reviewed all images and assigned them an STN visualization score (0=not visible, 1=poor visualization, 2=moderate visualization, 3=well visualized). A Wilcoxon signed-rank test was performed to compare STN image quality on QSM versus T2*W, and on QSM versus T2W.

Results

The average STN CNRs are summarized in Table 1. QSM showed a 6 fold improvement over the T2*W images ($p<0.001$), and an 8 fold improvement over the T2W images ($p<0.001$). An example case is illustrated in Fig.1, where a double dip in signal intensity – distinguishing the STN from the Substantia nigra – is seen on the T2*W and QSM plots, but not on the T2W plot, where only a single dip appears.

The average visualization scores assigned by the radiologist are reported in Table 1. A Wilcoxon signed-rank test performed on the image scores indicated a significant difference between STN visualization on QSM and on T2*W ($p<0.01$), as well as a significant difference between STN visualization on QSM and on T2W ($p<0.01$).

Table 1	Mean Contrast	Mean Noise	Mean CNR	Mean STN Visualization Scores
QSM	153 ± 23.8	2.76 ± .866	57.5 ± 23.1	2.9 ± .316
T2*W	242.15 ± 48.9	27.7 ± 5.60	8.93 ± 2.04	1.7 ± .483
T2W	190 ± 30.7	28.3 ± 4.62	6.87 ± 1.71	1.7 ± .823

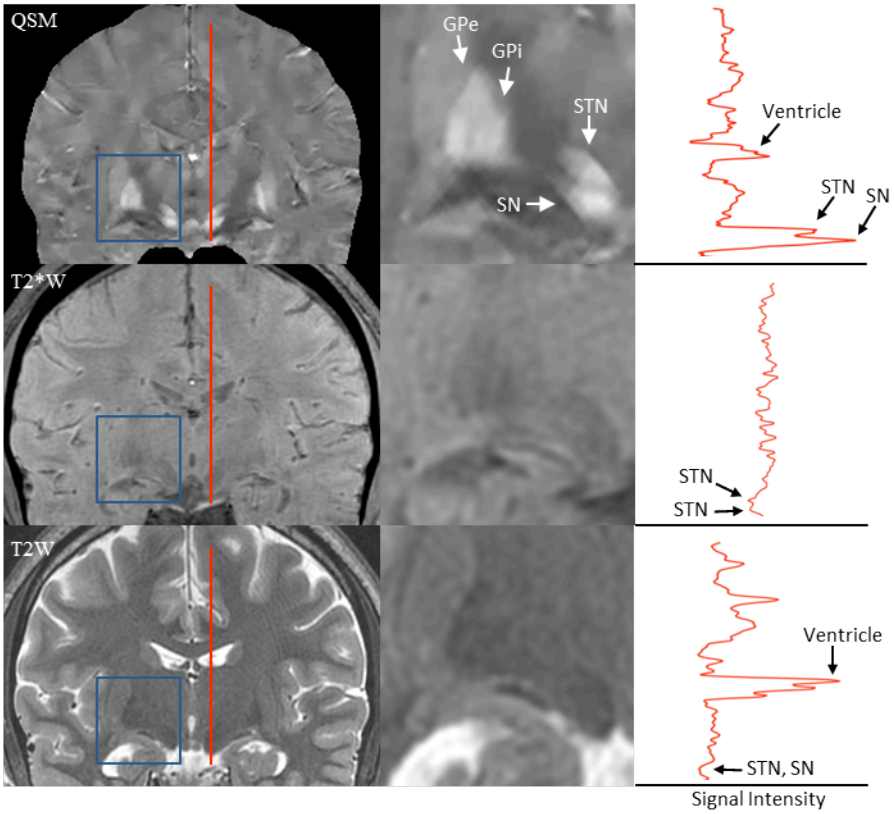

Figure 1: Coronal images of the STN, obtained using three different imaging modalities: QSM, T2*W, T2W. A sample vertical line drawn through the left STN with its corresponding 1D signal intensity plot is shown.

Conclusion

QSM provides better CNR for depicting the STN than conventional T2* weighted and T2 weighted imaging, and may be helpful to neurosurgeons planning deep brain stimulation procedures on Parkinson's disease patients.

References

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