Improved Visibility of the Subthalamic Nucleus on High-Resolution Stereotactic MR Imaging by Added Susceptibility (T2*) Contrast Using Multiple Gradient Echoes

SUMMARY: Reliable identification of the subthalamic nucleus (STN) is a critical step in deep brain stimulation for Parkinson disease but difficult on T1-weighted stereotactic MR imaging. By simultaneous imaging of multiple gradient echoes, susceptibility contrast is added to conventional T1-weighted high-resolution MR image. Thus, the visibility of the STN is enhanced on a second co-localized dataset by exploiting the sensitivity of the T2* -relaxation to local iron deposits. The feasibility is underpinned by quantitative measurements on healthy adults.

Results
The T2*-signal intensity decay was markedly faster in the area of the STN than in the surrounding tissue. Figure 1 shows representative curve fits to the STN and the reference region of the reticulate formation. This corresponded with a contrast of approximately 25% at the longest TE. Thus, both STNs could be identified in all 16 of the subjects even when motion artifacts impaired the delineation (2 subjects).

Figure 2 shows the midbrain region, where the solely T1-weighted data (echo 1; TE = 2.3 ms; top) did not reveal any structures, but the STN became clearly visible at a TE of 20 ms and above (echo 7; middle). The main axis of the STN was slightly oblique to the anterior/posterior commissure plane shown in Fig 2. Its position was approximately 7 mm rostro-anterior to the superior pole of the red nucleus. The spatial assignment was confirmed by comparison with the coregistered T2-weighted TSE images with the use of a stereotactic system. In the subject shown in Fig 2, the estimated position of the STN by using Schaltenbrand-Wahren coordinates was slightly different from the direct visually identified position. In addition, phase data were acquired to calculate the spatial distortions as a result of magnetic field inhomogeneities. Even in the critical areas at the skull base, these did not exceed 1 pixel.
Discussion
The correlation of iron deposits in the STN and the associated hypointensities on T2-weighted MR imaging has been firmly established by a histologic study\textsuperscript{4} and has been applied recently at 3T.\textsuperscript{5} This is the first report to use the higher sensitivity of T2* to local iron content\textsuperscript{6} for direct visualization of the STN. Comprehensible contrast could be obtained at short TE compatible with TR durations as used in high-resolution 3D T1-weighted MR imaging in clinically feasible time. We were able to demonstrate the T2* contrast of the STN also at 1.5T by using a standard quadrature head coil and a single echo measurement with TE at 20 ms. Implementation as a multiecho technique permitted simultaneous acquisition and, thus, inherently co-localized datasets without loss of resolution such as T2-weighted MR imaging and without additional measuring time. The dataset of the first echo may be used in standard stereotactic procedures; the later echoes provide additional contrast of iron-containing structures. The low heat deposition of the gradient-echo approach is an additional advantage at higher field strengths and in the presence of metal implants. However, the feasibility for postsurgical control is expected to be hampered by the presence of B\textsubscript{0} field inhomogeneity. Quantitative in vivo data of the iron content and relaxation in the STN are lacking, because this structure has not been evaluated in MR imaging studies.\textsuperscript{5,9} Further systematic evaluation on a larger cohort is in progress to fully evaluate the potential of the suggested technique and individual-, age-, and disease-related variations.

Conclusion
Because of the iron content of the STN and sensitivity of T2* to iron deposits, the STN can be visualized on stereotactic MR imaging by simultaneous acquisition of multiple gradient echoes at 3T to generate co-localized 3D datasets with T1 and T1-T2* contrast.

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