Midbrain imaging at 1.5 and 4T using Susceptibility Weighted Imaging: Optimizing the Imaging Parameters

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Introduction: The brainstem and the midbrain area in particular are important areas to examine when investigating neurodegenerative disorders like Parkinson's and Alzheimer's diseases. This region is well known to have changes in iron content and recently it has been shown that paramagnetic iron resides in the neuropil and is associated with vessels and vessel wall (1). Imaging this region with a method sensitive to those iron granules would provide not only valuable anatomical information but also give a clue about the way such neurodegenerative disorders are manifested. The goal of this work is to find the best MR sequences at 1.5 and 4T to image the midbrain.

Material and methods: Various conventional MR sequences were compared with the SWI scans. These included: T1-weighted 3D gradient echo, double echo spin echo T2-weighted, MRA with and without an MTC pulse as well as SWI with different echo times, resolution, TURBO factor and number of averages. The sequence parameters were adjusted to improve SNR and CNR values, as well as maintaining a reasonable scanning time. These scans were performed at both 1.5T (Siemens Sonata) and 4.0T (Bruker/Siemens Medspec). A total of 5 volunteers were imaged at both 1.5T and 4.0T in order to compare the results from the same individual at both field strengths. This protocol was approved by the institutional review board at Wayne State University and each subject signed a consent form.

Results: The best 1.5T sequence has the following parameters: 3D, flow compensated SWI sequence with a slice thickness of 2 mm, an in plane resolution of 0.5mm x 1.0mm, a BW of 130Hz, a TR of 71ms, a TE of 35ms, a flip angle of 20 degrees and 3 averages. The best 4T sequence is an SWI sequence with the following slight differences in imaging parameters: a resolution of 0.5mm x 0.5mm x 2mm, a TR of 29ms, a TE of 15ms, a flip angle of 10 degrees and a bandwidth of 50Hz. The filtered phase images acquired with those sequences compete as to quality and anatomical visibility with cadaver India ink-stained slices as presented in the 1999 primer by H. Duvernoy (2) and the work of Yakovlev from 1994 (3).

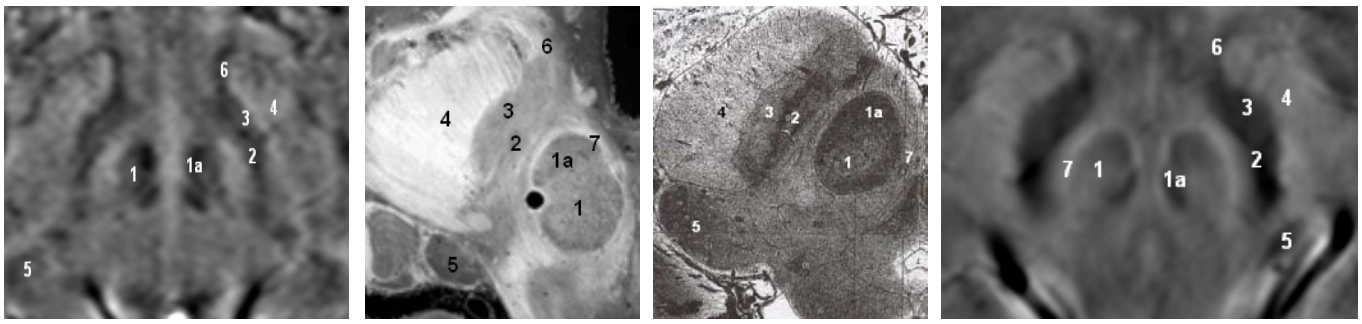

Figure 1: First left image: a phase filtered 1.5T SWI image. Second image from the left: anatomical ink-stained image from Yakovlev. Third image from the left: cadaver brain India ink-stained image from Duvernoy. Right image: phase filtered 4T SWI image. The regions of the midbrain are labeled as follows: 1. Red nucleus non-vascularized part 1a. Red nucleus vascularized part 2. Substantia nigra pars compacta 3. Substantia nigra pars reticulata 4. Crus cerebri 5. Medial geniculate body 6. Fasicula nigrale 7. Capsule of Red nucleus.

Discussion and Conclusion: The match between SWI filtered phase images and the cadaver ink-stained pictures in Duvernoy's anatomy book on the vessels in the brainstem (2) and in Yakovlev's specimen work (3) is remarkable. The fact that SWI is sensitive to iron content and that iron is so prevalent in these structures in the form of iron granules in the neuropil makes SWI the method of choice for this type of anatomical detail. The best results in terms of SNR and CNR were obtained with a resolution of 0.5mm x 0.5mm with a 2mm slice thickness at 4T. This would have been true at 1.5T as well if we were allowed a longer scanning time. However, at 1.5T we kept the scanning time more reasonable by using only 0.5mm by 1.0mm in-plane resolution. Calculating iron content in a region of interest with n pixels using SWI filtered phase images yields an estimate of the iron concentration, c(Fe), given by:

$$c(Fe) = \frac{\left(\varphi_{CSF} - \bar{\varphi}\right)}{3} \pm \frac{30}{\sqrt{n}} \quad ; \qquad \text{(where the units of iron concentration are in mg Fe/gm tissue)}$$

assuming SNR of 23:1. This is 7.6 times more sensitive a measurement than the conventional R_2^* approach using the same SNR of 23:1. Given the potential role of iron in many neurodegenerative disorders, this sequence may play an important role in the future as a means to obtain high resolution, high contrast anatomical images of the midbrain that can also be used to measure iron content.

References:

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