Quantitative Susceptibility Mapping (QSM) in Wilson’s Disease
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PURPOSE: Accumulation of metallic compounds in the human brain has been shown in some neurodegenerative diseases. In Parkinson’s disease iron content seems to be increased in the basal ganglia [1], whereas in Alzheimer’s disease zinc and iron are increased [2]. Recently it was shown that quantitative susceptibility mapping (QSM) is very sensitive to paramagnetic effects of iron [3], supporting the differentiation of Parkinson patients from healthy controls using MRI and QSM [4]. Wilson’s disease is a neurodegenerative disease with symptoms rather similar to Parkinson’s disease and other movement disorders, but in Wilson’s disease the copper content is increased [5]. The aim of this study is to investigate whether copper accumulation in the brain of Wilson’s patients can be detected using QSM, by comparison with healthy controls.

METHODS: 8 patients with Wilson’s disease (23-64 years, mean 44 years, 4 female) and 10 age-matched healthy controls (27-61 years, mean 45 years, 5 female), who gave informed consent, were examined on a whole body 7T scanner using a 24 channel phased array coil. The study was approved by the local ethics committee. For imaging a 3D spoiled gradient multi-echo sequence (TR=40 ms; TE=9.76/19.19/28.62 ms; bw=150 Hz/pixel; voxel=0.6x0.6x0.8mm³) was used.

The phase data, which show the effects of a field perturbation $B_d(r)$, were unwrapped using a 3D best-path phase unwrapping algorithm [6]. The SHARP algorithm was used to remove any $B_0$ inhomogeneities and thus obtain high-pass filtered phase data [7]. The filtered phase data were divided by $\gamma B_0$TE to convert the field-shift to units of ppm. The data were re-sampled to 0.6 mm isotropic resolution. The susceptibility was then calculated by $\chi(r) = FT^{-1}(-3B_d(k)/B_0C^+(k))$, where $B_d(k)$ is the field perturbation in k-space, $B_0$ the main magnetic field and $C(k)=3k_2/|k|^2-1$ the convolution kernel. Before inverse Fourier transform values of the convolution kernel smaller than 1.3 were set to $\text{signum}(C(k))·1.3$ to reduce noise amplification and minimise streaking artefacts [8]. So far we only analysed the Substantia Nigra (SN).

RESULTS: Figure 1 shows an example of the gradient echo magnitude image, phase image and the calculated QSM for one patient. The average value of the susceptibility of the SN is 0.23±0.08 ppm and 0.13±0.03 ppm for patients and healthy controls, respectively. Figure 2 shows the susceptibility of the SN of the Wilson’s patients (red) and healthy controls (green). 6 out of 8 patients show an increased susceptibility within the SN compared to healthy controls.

DISCUSSION: Our data clearly show that the SN is more paramagnetic in Wilson’s disease patients compared to healthy controls. The remaining question is: What induces the change in magnetic behavior? The element copper is only slightly more paramagnetic than water, and copper(II)-compounds are even more diamagnetic than water [9]. One possible explanation is that copper(II)-compounds, which mostly have strong paramagnetic behavior, yield the increased paramagnetic behavior of Wilson’s patients.

CONCLUSION: We have successfully applied QSM to Wilson’s disease patients. There is a trend that paramagnetic copper(II) induces the magnetic susceptibility changes in patients as compared to controls. Further investigations will include quantitative T1 mapping, since copper(II) also enhances the longitudinal relaxation rate [10].

REFERENCES: