Imaging and analysing iron accumulations in the human brain using magnetic resonance imaging

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Introduction:

It is known that iron accumulations occur in brains of patients with diseases such as Parkinson's disease (PD) [1] or Alzheimer's disease. The aim of our study was to visualize and analyze such iron stores by using magnetic resonance imaging [2, 3]. It has been shown previously [3] that the susceptibility-weighted imaging (SWI) phase is proportional to the iron stored in tissue. Here an approach to analyze SWI phase data in terms of phase shift and phase shift-symmetry is presented. Our hypothesis was that PD patients have an elevated phase shift in the posterior part of the Putamen and that lateralized symptoms of PD patients should be reflected by lateralized phase differences.

Methods and Materials:

Phase data from seventeen people (twelve patients with PD and five healthy controls) were used to determine differences in terms of phase shift and phase shift-symmetry. A three-dimensional, fully first-order flow-compensated gradient-echo (SWI) sequence with a TE of 29ms was used to acquire phase data at 3T. Other sequence parameters were: TR = 36ms; image-matrix = 256x256 pixel; slices = 176; GRAPPA factor = 2, TA = 17,22 min, resolution = 0.8 mm isotropic. The phase images were filtered using an equivalent to Homodyne filtering with a Gaussian filter kernel (fwhm 5mm in image space). In order to perform phase shift-symmetry comparisons and prevent bias due to shape differences, a symmetric phase model was build by using the approach presented by [4]. Regions of interest (ROIs) for the Putamen (Put) and the Globus pallidus (GP) were labelled manually. The ROI for the Put was split into three sub regions (anterior, medial and posterior) which are presented in Fig. 2. All data-sets were linearly and non-linearly registered to the symmetric model and flipped along the midline. To determine phase shift-symmetry 3D correlation coefficients (r) were calculated by using the masked (with the ROIs) aligned and the masked flipped data-set. Phase shift comparisons were done by transforming the ROIs from the phase-model into the individual subject's space. Mean phase-shift values (from positive values only) and standard deviations were calculated by using the transformed ROIs.

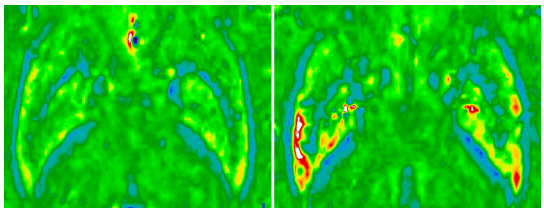

Fig. 1: Phase shift example in the area of the Putamen and the Globus pallidus. Data from a control subject on the left and data from a PD patient on the right. Note the difference in terms of phase shift symmetry in the Putamen. Data from the PD patient show uneven spread areas with higher phase shifts (r =0.27) compared to the data on the left (r =0.45).

Results:

PD patients showed a 44% higher mean phase-shift (which is proportional to the iron concentration) in the GP and a 10% higher mean phase-shift in the Put compared to healthy controls. The posterior part of the Put (patients and controls) demonstrated a 57% higher mean phase-shift compared to the anterior part with the mean for patients above the one for controls in all areas. Symmetry evaluation shows that two out of three patients with symmetric PD have a higher correlation coefficient, i.e. show a high symmetry (0.49 and 0.44 by an average of 0.43 over the patient cohort). The smallest third of correlation coefficients belongs to PD patients with clearly lateralized symptoms.

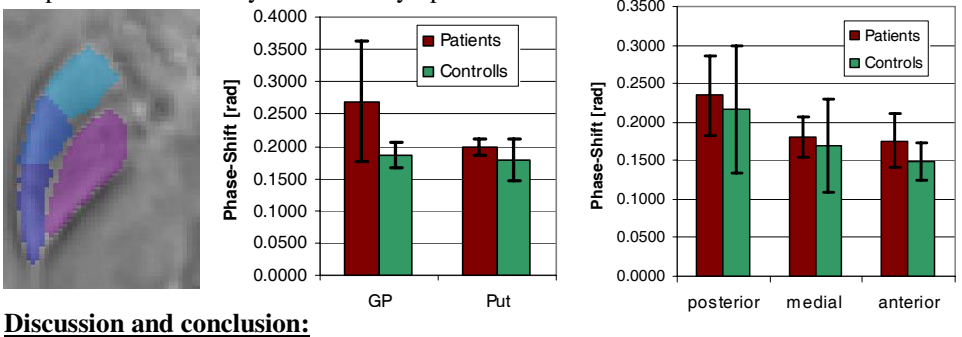

Fig. 2: Left: Symmetric phase model overlaid with a ROI split in PD relevant sub ROIs (GP in magenta, Put posterior in midnightblue, Put medial in medium blue, Put anterior in light blue). Middle: Analysis of phase shift caused by the GP and the Put. Right: Mean phase shift analysis of the in three sub regions (posterior, medial and anterior; left and right averaged) divided Put. Bars represent the standard deviations.

Discussion and conclusion:

As subcortical structures in the brains of patients with PD tend to accumulate iron the phase-shift symmetry is a possible marker for unilaterally PD. Using the symmetric phase model as applied here, a direct (image based) symmetry comparison between the lateralized structures such as Put is made possible despite shape differences. Furthermore, phase-shift symmetry is based on correlation of phase values in lateralized structures and thus largely independent of absolute phase-values that are more difficult to interpret.

References:

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