Correlating phase with iron content in Alzheimer's Disease

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Introduction: MRI offers the potential to perform high resolution imaging of iron content in the brain and the presence of age related micro hemorrhages. We have developed an approach using phase information to attempt to correlate iron content throughout the brain for normal and Alzheimer's disease (AD) patients. Our goal is to see if changes in iron content correlate with changes in mental acuity or progression of AD.

Methods: The structural and physiological composition of tissue plays an important role in determining the local magnetic field behavior of a given physical region in the brain. MR imaging is sensitive to this variation in magnetic field or susceptibility of the tissue through its phase. Hence measuring the phase difference between tissues can be a marker for iron content, blood or other sources of susceptibility change. The phase images serve as a direct measure of these magnetic field variations. We collected a set of 3D gradient echo images at 1.5T with an echo time of 40ms. The phase images were high pass filtered to remove low spatial frequency components. The phase (φ) is equal to $-\gamma\Delta BTE$ where γ is the gyromagnetic ratio, ΔB is the change in magnetic field and TE is the echo time. Iron is a paramagnetic element, making ΔB positive. We have measured the phase in a number of areas in the brain including: the motor cortex, putamen, caudate nucleus, globus pallidus, red nucleus and substantia nigra.

Results: To date, 72 patients/subjects have been analyzed once. Figure 1 shows our ability to separate gray matter from white matter and CSF. The means and standard deviations were as follows: gray matter 1940/25; white matter 2060/25 and CSF 2120/30. Clearly, the mean for GM is well separated from that of CSF by more than 6 standard deviations. Figure 2 is a plot of phase in the red nucleus. There is a long tail of large phase shifts, indicating larger iron content for these cases. Similar results are seen in the putamen and globus pallidus, which may be associated with mineralization or an increase in iron content caused by some physiological change. Specifically, in the putamen, iron deposition appears in the lower portion and then spreads to the upper parts (Figure 3).

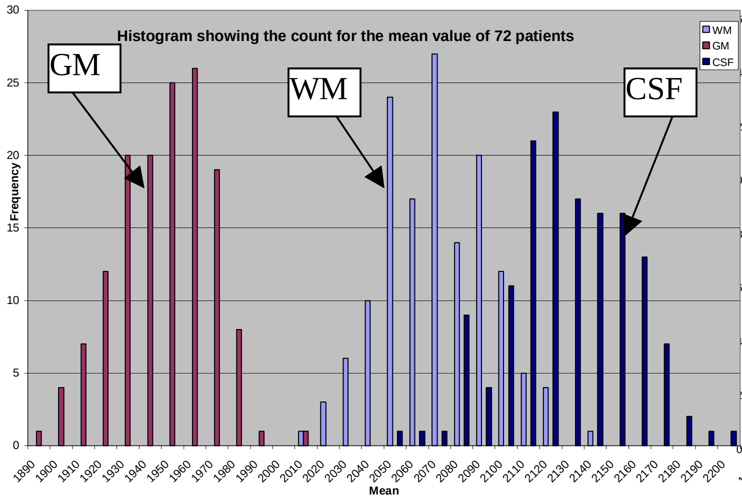

Figure1: Histogram of phase values from WM, GM and CSF taken from motor cortex.

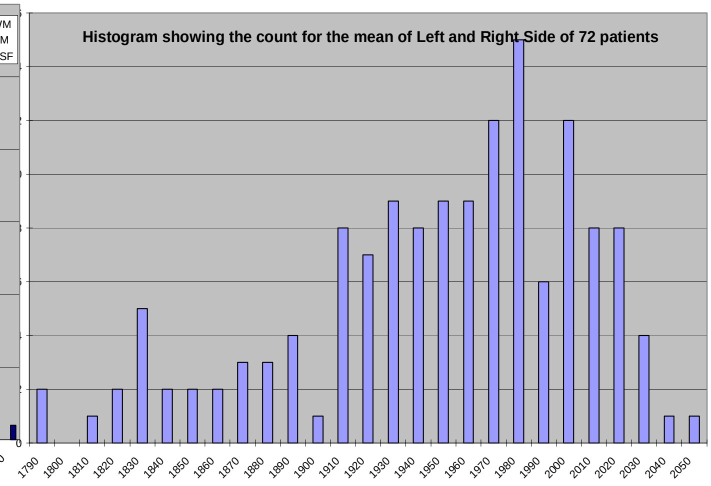

Figure2: Histogram of phase values from Red Nucleus.

Figure 3: Left Putamen

Discussion: After studying 72 data sets, we have found that the variation in phase follows a Gaussian statistics with a standard deviation for the distribution of errors of about 25 to 30 units. Any deviations from say three standard deviations or 90 units might then be called a significant variation. Our goal is to correlate disease or pathological variations with abnormalities revealed by this phase analysis.

Conclusion: It is possible to obtain a normal distribution of phase for a number of structures in the brain. Measuring phase in some parts of the basal ganglia in an MR image and relating it to iron content may have the potential to correlate with the severity of AD. However, much more data needs to be acquired before any conclusions can be drawn. We plan to collect data serially over 4 years and look for phase changes that correlate with changes in the neuro-psychological testing. The data presented here will serve as an important basis for using phase imaging in the future in the assessment of iron deposition and possibly in following changes in iron content with pathology.