Quantitative iron mapping in human brain based on the apparent transverse relaxation time

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Introduction

Iron is an essential element in human body, but its overabundance is toxic through the production of reactive oxygen species. Recently it has been reported that the occurrence of neurodegenerative diseases like Alzheimer's and Parkinson's diseases are closely related to the presence of regional iron [1]. Therefore, quantitative iron mapping in human brain would be worth attempting not only for visualizing physiological distribution of iron in the brain but for understanding and diagnosing various brain diseases. We have clarified that the apparent transverse relaxation rate ($R_2^\dagger$) obtained using a multiecho adiabatic spin echo (MASE) sequence [2] is well explained with a linear combination of the regional non-hemin iron concentration [Fe] and the macromolecular mass fraction f_M defined as 1 – water fraction [3]. In the present study we attempted to visualize distribution of nonhemin iron in normal and diseased brains based on the relationship between $R_2^\dagger$, [Fe] and f_M.

Materials and Methods

Human brain $T_2^\dagger$ measurements were conducted on 22 healthy volunteers and a patient with cavernous hemangioma using a MASE sequence at 4.7T as previously reported [2, 3]. $T_2^\dagger$ and M_0 maps were generated by a single exponential curve fitting to the signal intensity of each pixel in the obtained six echoes. We calculated an iron map using both of the $T_2^\dagger$ and M_0 maps. But, unfortunately signal intensity in the M_0 map was distorted by RF interference effects at high field. We recently developed a method to correct the distortion assuming that B_1^- is expressed as a function of B_1^+ in human brain [4]. B_1^+ was experimentally measured by a phase method using an adiabatic spin echo sequence with TR/TE = 500/30ms [5]. Signal intensity in various regions of brain in the corrected M_0 map was consistent with the previously reported water fraction in the brain. Then, a map of f_M was generated from the M_0 map, and an iron map was calculated using an equation of $R_2^\dagger = 0.47[Fe] + 24.9f_M + 9.54$ obtained in a separate group of 38 healthy subjects [3]. T_2-weighted images throughout the brain were also obtained on 40 slices using a fast spin echo sequence with TR/effective TE = 20000/60ms, echo train = 12, slice thickness = 2.5mm, data matrix = 256 x 192, and the number of accumulation = 1.

Results and Discussion

Figure 1a shows a T_2-weighted image across the basal ganglia region in a healthy subject (21-year-old female), and Figure 1b shows an iron map obtained in the same plane. It is obvious that basal ganglia has high iron. [Fe] in the globus pallidus region was over 20 mg/ 100g fresh wt. Most occipital and some temporal cortices also have high iron, sometimes over 10 mg/ 100g fr. wt. This was much higher than [Fe] in neighboring white matters. On the contrary, posterior limb of internal capsule and optic radiation have negligible iron. These appearances and [Fe] values were consistent with the iron distribution reported previously [6]. An iron map obtained from a patient with cavernous hemangioma (67-year-old female) reveals additional high [Fe] accumulation of ~30mg/100g fr. wt. (arrow in Fig. 1d) corresponding to the low signal intensity area next to left occipital horn of lateral ventricle on the T_2-weighted image (Fig. 1c). Iron distribution in other regions in this map is quite similar to that in the normal brain.

Conclusion

Iron mapping in human brain based on $R_2^\dagger$ expressed as a linear combination of [Fe] and f_M was demonstrated on normal and diseased brains. This method visualizes iron distribution in the brain, and could be a potential tool for understanding iron-related diseases.

References

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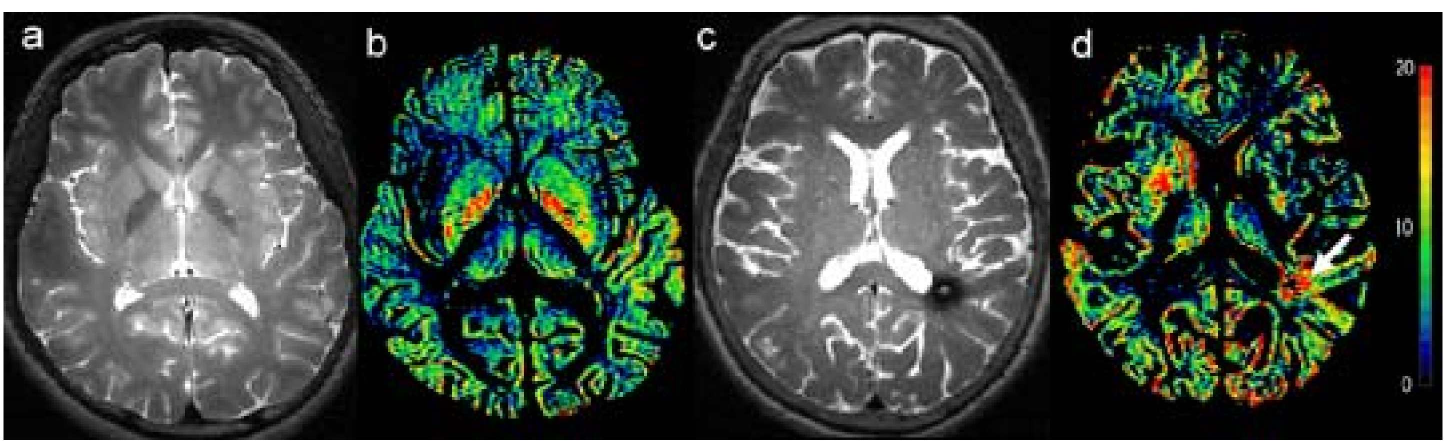

Fig.1. T_2-weighted images (TR/effective TE = 20000/60 ms, slice thickness = 2.5 mm) and iron maps in normal and diseased brains. (a) T_2-wt image across basal ganglia in a healthy subject, (b) iron map on the same plane as (a), (c) T_2-wt image in a patient with cavernous hemangioma, and (d) iron map on the same plane as (c). Arrow indicates unusual iron accumulation in the hemangioma. Color bar on the right shows [Fe] in mg/100g fresh weight for (b) and (d).