Electrical Conductivity Images of Brain Metabolites using MR-based Tissue Property Mapping

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Target audience

This study might be helpful to the researchers who are interested in the practical applications of MR-based electrical tissue property mapping methods such as MREIT and MREPT.

Purpose

The purpose of this study is to show new approach of brain metabolites mapping with highly sensitive to their concentration changes using MR-based electrical conductivity imaging method.

Methods

To investigate the relationship between concentration and electrical conductivity of brain metabolites including NAA; N-acetyl-L-aspartic acid, Cr; creatine, Cho; choline, Ach; acetylcholine, mI; *myo*-Inositol, Glu; glutamine & glutamate, Lac; lactate, we directly measured the actual conductivities of each brain metabolites by changing their concentration using an impedance analyzer (SI1260A, AMETEK Inc., UK) (Fig. 1a). Since the conductivity values of NaCl solution by the concentration changes are well known, the measured values of each metabolite were compared with the values of NaCl to evaluate the degree of conductive. For phantom imaging, a cylindrical acrylic phantom (12 cm diameter and 16 cm height) consisted of saline solution and four different concentrations of agarose anomalies with 0, 5, 10, and 20 mM, respectively, in a form of a hollow cylinder were used (Fig. 1b). Four carbon-hydrogel electrodes were attached on the sides of the phantom and was placed the phantom inside the bore of 3T MRI scanner.

Using a current source, the imaging currents (I_1 and I_2) were injected between one opposing pair of electrodes, respectively (Fig. 1b). The injection current amplitude was 10 mA with the total pulse width of 30 msec. The multi-spin-echo ICNE pulse sequence was used to obtain the MR magnitude and magnetic flux density (B_z) images.[1] The imaging parameters were as follows; TR/TE = 800/15, 30, 45 msec (3 echoes), FOV = 160×160 mm^2, slice thickness = 3 mm (8 slices), NEX = 8, matrix size = 128 × 128, and total imaging time = 30 min. We obtained two different sets of data from *in vitro* phantom imaging. One is data from agarose anomalies of single metabolite without any other metabolites (marked "metabolite only"). The other is data from agarose anomalies of single metabolite with other metabolites having a fixed concentration of their natural condition in living tissue (marked "metabolite dominant"). After the imaging, absolute conductivity image was reconstructed from the measured B_z by the projected current density method.[2]

Results and Discussion

Figure 2 shows the results of direct measurement of actual conductivities from each brain metabolites with the changes of their concentration. Compared with the results of NaCl solution, choline and acetylcholine showed similar relationship between concentration and electrical conductivity. Although the natural abundance of each metabolites more or less different, choline is the most conductive material among the brain metabolites which can be measured by ^{1}H MRI technique.

Figure 3 shows conductivity images of phantom from two different conditions of "metabolite only" (Fig. 3a) and "metabolite dominant" (Fig. 3b). The conductivity images of choline showed clear contrast with the changes of its concentration in both two conditions. The images of NAA also showed contrast but its sensitivity was poor than that of choline. It means electrical conductivity-based choline mapping has a potential to potentially detect brain tissue abnormalities with high sensitivity. There was no significant conductivity contrast in other metabolites.

Conclusion

In this study, the conductivity images of choline showed highly sensitive with the changes of its concentration among the brain metabolites. Since the choline is regarded as a tumor marker and/or cell wall marker in brain diseases, the conductivity-based choline mapping is promising for the detection of brain tissue abnormalities.

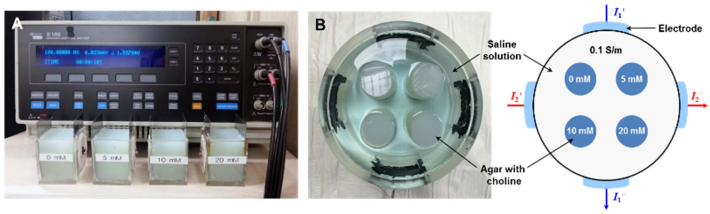

Fig. 1. *In vitro* measurements of electrical conductivity by the concentration changes (a) and setup for phantom imaging (b).

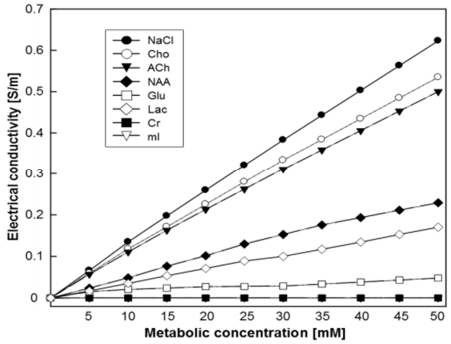

Fig. 2. Graph for relationship between concentration and measured electrical conductivity of brain metabolites.

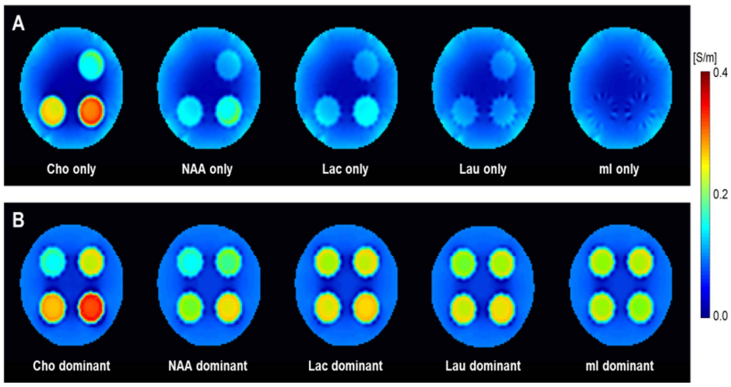

Fig. 3. Electrical conductivity-based brain metabolites mapping at two different conditions representing "metabolite only" (a) and "metabolite dominant" (b).

References

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2. Sajib SZK, Kim HJ et al. Regional absolute conductivity reconstruction using projected current density in MREIT. Phys. Med. Biol. 2012;57:5841-5859.