T1 Reduction by Applying a Small Amount of Electrical Currents

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Introduction

In the field of MRI, the spin-lattice (T1) relaxation time is one of the most indispensable intrinsic factors which prevent a reduction in the total scanning time. Since the tissues of the body have different molecular structures, each tissue has a characteristic T1 relaxation time. This value cannot be altered unless, for example, the temperature is changed or paramagnetic contrast media is administered. In this paper, we introduce a newly created technique to dramatically shorten T1 values by applying a small amount of electrical currents and to totally reduce the scanning time.

Principles

Molecular dipoles of water experience either an attractive or repulsive force and react to external fields. The dominant electrostatic interaction in water is the hydrogen bond. Liquid water has a few hydrogen bonds per molecule. In biological systems, water contains a multitude of salts, which exist in the form of dissociated charged ions. Water molecules form hydration shells around salts. Hydration shells are semi-stable structure of water molecules that interact with their dipole moment to the central point charge more strongly than they do with themselves. The charged particles move together with the hydration shells when an external electrical field is applied. By the combined movement with ions, free thermal motions of water molecules are supposedly restricted, resulting in the elongation of correlation times. The elongation of correlation times leads to reductions of T1 values.

Materials and Methods

Experiments were conducted using a 7.05-T, 18.3-cm bore MRI system. An acrylic column with a 26 mm inner diameter and 45 mm in length was filled with a 1.0 wt % saline solution, and platinum electrodes were installed at both ends of the column. A direct electrical field was applied parallel or vertical to the main static field B0. By a fast low-angle shot (FLASH) sequence (Tr = 60/ Te = 6), T1-weighted images of the phantom were obtained in various slicing directions with and without direct electric currents. Graphite planar electrodes were placed at both the anterior and posterior positions of the neck of a rat. T1-weighted images of the rat were also obtained by a spin echo (SE) sequence (Tr = 500 / Te = 14) with and without direct electric currents via the electrodes.

Results and Discussion

Figure 1 (left) shows the phantom image with the electrical currents of 1.0 mA/cm ^{2}, and Fig. 1 (right) shows the image without the currents. The signal intensitiesy with electrical currents increased significantly compared with those without electrical currents. This was similar to the effect of adding strong paramagnetic contrast media to the solution. The increase was also apparent in other slicing directions that were parallel to the electrical currents. An arterial spin labeling sequence confirmed that no significant flow-in effects of unsaturated spins to enhance the signal intensity were associated with the electrical currents.

Figure 2 (left) shows the rat image with electrical currents of 7.0 mA, and Figure 2 (right) shows the image without the currents. The signal intensities with electrical currents were higher than those without electrical currents. Though tissues with cells are much different from the saline solution phantom, it was confirmed that the effects of electrical currents also occurred in a living rat.

By applying a small amount of electrical currents, T1 relaxation times are significantly shortened. The technique is expected to provide a means to reduce the total scanning times of MRI. In addition, since electrical densities in tissues are related to the reduction of T1 values, the technique also has the potential to non-invasively detect conductance distributions of tissues.

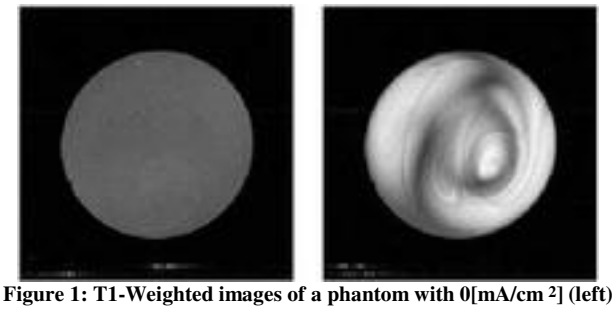

Figure 1: T1-Weighted images of a phantom with 0[mA/cm ^{2}] (left) and 1[mA/cm^2](right)

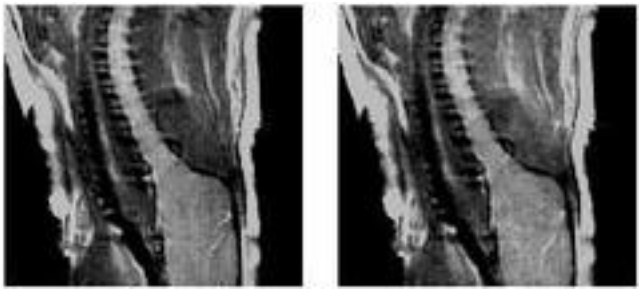

Figure 2: T1-Weighted images of a rat with 0[mA] (left) and 7[mA] (right)