Magnetic Field distortion caused by intracapillary red blood cells

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Introduction

Each red blood cell (RBC) that discretely flows through a capillary distorts the magnetic field of magnetic resonance imaging (MRI). This distortion spreads over a micrometer range around the RBC and moves along the capillary (Fig. 1), causing fast transverse relaxation. We investigated the changes in this fast transverse relaxation that occur due to blood oxygenation changes.

Materials and Methods

A single brain slice of a male volunteer was imaged using a 1.5-T MRI (Signa LX, General Electric) every 60 s for 50 minutes using a fast spin echo pulse sequence with short (5.2 ms) and long (88 ms) echo times (TE). To avoid the fluctuation of the inflow effect, long TR (6 s), which is enough to wash out the blood from the slice, was employed. The other scan parameters were as follows: ETL = 32, slice thickness = 5 mm, FOV = 260 × 260 mm^2, matrix size = 128 × 128, NEX = 1. The signal intensity at the sagittal sinus was measured and the changes in venous blood oxygenation were calculated. To observe the influence of the changes in the magnetization of the blood, 20 cm^3 of the Gd-DTPA contrast agent (Omniscan) was administrated ten minutes after the start of the imaging. Although the contrast agent decreased the T1 of the blood, the signal was insensitive to T1 because of the long TR. The signal intensities at 6 circular ROIs (diameter = 30 mm) in brain parenchyma were measured and averaged.

Results and Discussion

The blood oxygenation decreased at 10% gradually during the 50-minute experiment and the signal intensities of the brain both for short and long TE also decreased gradually except for the period influenced by the contrast agent (Fig. 2). The administration of the contrast agent decreased the signal intensity of the brain parenchyma significantly (2%) for long TE but for short TE (dotted arrow in Fig. 2). The contrast agent changes the transverse relaxation rate (R2) of the blood and the rate of the signal changes is given as ⊿R2 · TE where ⊿R2 is the change in R2. Following this formula, the rate of the signal changes due to ⊿R2 of the blood for short TE is calculated as small: 2% × 5.2/88 = 0.1% . Since the magnetic field distortion depends on the difference of the magnetization between the RBC and the plasma, an increase of the magnetization of the plasma due to the contrast agent changes the magnetic field distortion. However, this distortion increases in the arterial side and decreases in the venous side, being commensurate through capillaries. Therefore, the influence of the contrast agent is small for the signal obtained with short TE. On the other hand, the signal for long TE likely stayed constant during the decrease of the concentration of the contrast agent (red data in Fig. 2). Since the blood oxygenation supposed to gradually decrease also in this period, the small changes of the signal for long TE may reflect counterbalancing the magnetization of the RBC and the plasma. The magnetization of the RBC increased due to a decrease in blood oxygenation and that of the plasma decreases due to the washout of the contrast agent. The blue data in Fig.2 showed the influence of an increase in the RBC magnetization following the decrease in blood oxygenation. The slope of the regression line of these blue data revealed that changes of the R2 observed at short TE is twelve times larger than those observed at long TE.

Conclusion

Changes in the fast relaxation in brain parenchyma due to the RBC magnetization were large, indicating the strong distortion of the magnetic field caused by intracapillary RBCs.

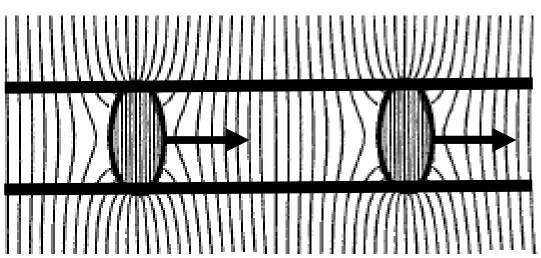

Figure 1 A magnetic field distortion model around the RBC that discretely flows through a capillary. The paramagnetic deoxygenated hemoglobin increases the magnetization of RBCs.

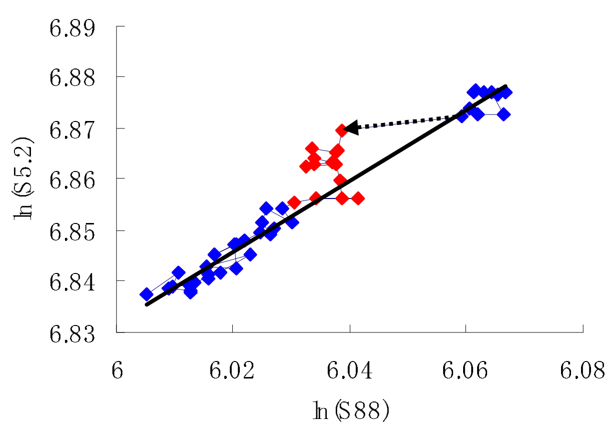

Figure 2 A Scatter plot of the logarithmic signal intensities for short (S5.2) and long (S88) TE in brain parenchyma. The right most point is the initial data. The dotted line shows the change due to the administration of the contrast agent and the data until 15 minutes after the administration were marked in red.