NOTE

Serial Measurement of Relative Changes in Net Magnetization II : Assessments of Its Sensitivity with a High-Field Magnet

Yoshiki KANEOKE[1], Masahiro FURUSE[2], Akira IZAWA[3], Akira KASAI[4]

[1]*Department of Neurology, Emory University School of Medicine Woodruff Memorial Building Suite 6000, P.O. Drawer V. Atlanta, GA 30322 U.S.A.*
[2]*Department of Neurosurgery and* [3]*Radiology, Nakatsugawa Municipal General Hospital*
[4]*Shimadzu Corporation*

We assessed the variability of MR signal intensities from the ROI of a phantom bottle measured by the image of a conventional spin-echo pulse sequence. Frequency analysis showed that the intensity varied in the range of ±1.0% with a cycle of 53 minutes. In contrast, the ratio of the signal intensities from two ROI had no time dependent change and the coefficient of variation was approximately 0.2%. This shows that we can detect minute (less than 1%) changes in signal intensities from a localized region by measuring the ratio of a region of interest and a reference region. We confirmed this estimation assessing the effect of sodium acetazolamide on the brain. About 0.33% of the increase of a localized brain tissue signal intensity was detected from the value in the ratio of the brain and a phantom signal intensity. We may make use of this method to detect changes in cerebral blood volume related to the brain function though further study is needed.

INTRODUCTION

Net magnetization is one of the major factors which effects the intensities of MR signals. However, it has rarely been used in magnetic resonance imaging (MRI) because of its poor variability in tissue discrimination compared with that of relaxation times. In our previous study[1)] we showed that the relative changes in net magnetization could be utilized as a parameter to detect tissue blood volume. The Main problem with this method is that the changes in net magnetization related to tissue blood volume are expected to be less than 1%. Though we can assess the relative changes in net magnetization by measuring the relative changes in MR signal intensities acquired by using the same radio frequency (RF) pulse sequences, conven-

Keywords : magnetic resonance imaging, net magnetization, serial measurement of MR signal intensity, cerebral blood volume, sodium acetazolamide

tional methods to measure MR signal intensities can not measure such minute changes in net magnetization because of the time dependent variance of the power for the radio frequency (RF) transmitter. This usually varies MR signal intensities in a few percents.

We propose in this paper a method to detect minute changes in MR signal intensities from localized human tissue varied with tissue blood volume using a high-field MR imager.

METHODS

First, we measured the variability of the MR signal intensities from two phantom bottles which contain 7 and 10mM $NiCl_2$ for approximately one hour. Second, we assessed the effects of sodium acetazolamide on the MR signal intensities from the localized brain tissues of 3 healthy male volunteers.

MR signal intensities were measured using the MR imager with 1.5T superconducting magnet (SMT-150, Shimadzu Co., Kyoto). We assessed the mean signal intensities serially from the region of interest (ROI) determined with images constructed by the ordinal spin-echo pules sequences. The condition is as follows ; repetition time : 500ms, echo time : 20ms, 4 excitation, 256×128 matrix with the two-dimensional fast Fourier transform method, field of view : 250mm, section thickness : 60mm for phantoms ; 40mm for the brain. The diameter of the ROI for the phantom bottle is 2.5cm and that for the brain is about 2.0cm. Acquisition times are about 2 minutes for the phantom study and 4 minutes for the brain and phantom study.

RESULTS

Time courses for the relative changes in the MR signal intensity from the two phantom bottles (serial 20 times) are shown in Fig. 1(A). The main cause of the time dependent variance was due to the power drift of the RF transmitter. As shown in Fig. 1(B), frequency analysis with the maximum entropy method showed that the signal intensity varied with a cycle of about 53 minutes. The amplitude of the cycle was up to ±1.0%. When we calculate the ratio of both phantom signal intensities, the values varied within 0.2% and there was no time dependent change (Fig. 1).

In an assessment of the effects of sodium acetazolamide on the signal from the brain, we measured the relative changes in the ratio of signal intensities from the two brain ROI and the phantom ROI in each subject. Fig. 2 shows the ROIs for the brain and phantom. We measured signal intensities serially 6 times (3 times were done prior to acetazolamide infusion) in 3 volunteers. Table 1 shows the mean signal intensity ratio of the brain and the phantom ROI before and after acetazolamide intravenous infusion (1g in 10ml water). Significant increases (mean : 0.33%, $p=0.014$, Wilcoxon test) were seen in the values of the ratio.

DISCUSSION

In our previous paper[1], we showed that minute changes (less than 1%) of MR signal intensities could be measured by the proce-

Received Jun 29, 1992
Correspondence in Japan : M. Furuse, Nakatsugawa Municipal General Hospital, Komanba, Nakatsugawa City, 508

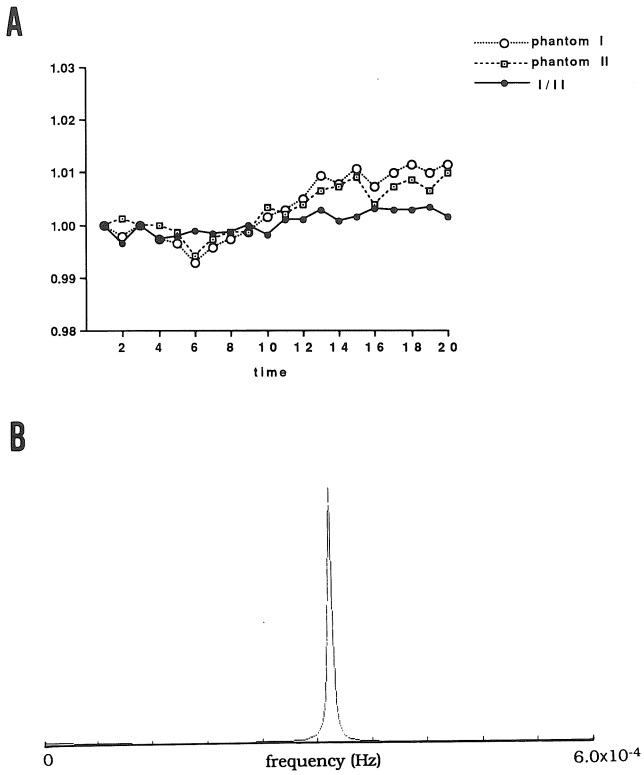

Fig.1.

A : Relative changes in signal intensities from the two phantom bottles. The ratio of the two data sets shows no time dependent variance in contrast to the each data set. B : The frequency analysis with the maximum entropy method indicates that the moving averaged (5 points) signals from the phantom bottle I varied at the cycle of 53 minutes and the amplitude is approximately ±0.7%.

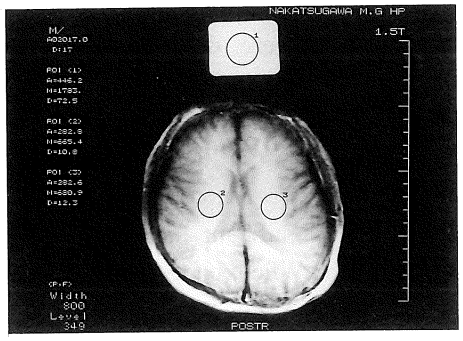

Fig.2.

This MRI shows the position of the phantom bottle and the ROIs for the brain. The phantom bottle is placed to minimize the noise that is produced by it which affects the brain image. The brain ROIs were determined including the least amount of fluid.

dure which stabilizes RF power drifts. But we could not assess the changes from the localized human tissue owing to the low magnetic field strength (0.043T).

In this study we failed to stabilize the RF power of a high-field MR imager (1.5T) probably due to its high RF power compared with that of low-field MRI. To diminish this time dependent variance of the RF power, we measured the ratio of MR signal intensities from two different ROI. There was no time dependent change in the ratio of the two phantom bottle signal intensities and the coefficient of variation was around 0.2% (Fig. 1). The results indicate that the effect of RF power drift on signal intensities were

Table 1. The mean signal intensity ratio (brain/phantom ROI in percent) before and after 1g sodium acetazolamide infusion (mean±S.D.) and the difference between them (those before infusion).

subject	before infusion		after infusion		differences	
	ROI 1	ROI 2	ROI 1	ROI 2	ROI 1	ROI 2
1	36.7±0.09	37.9±0.06	36.9±0.15	38.2±0.17	+0.2	+0.3
2	23.6±0.20	24.3±0.23	24.0±0.11	24.9±0.07	+0.4	+0.6
3	36.7±0.07	37.0±0.12	37.0±0.07	37.2±0.07	+0.3	+0.2

mean difference : 0.33±0.15

(There were signiaicant (p=0.014, Wilcoxon test) increase in the values before and after the infusion.)

canceled out and we can measure relative changes of MR signal intensities from a localized area in the order of less than 1% by this method.

We confirmed the above speculation by the measurements of relative changes in the ratio of MR signal intensities from the brain and the phantom bottle. We detected the effect of sodium acetazolamide on the signal intensity ratio and the increase was about 0.33% (Table 1). This should be due to the increased brain blood volume after intravenous injection of lg acetazolamide. The brain blood volume increase about 10% by 1g acetazolamide infusion as reported by Sabatini et al.[2]. This increases water content of the brain and that results in the increase of the net magnetization.

Sabatini et al.[2] also showed that the brain blood flow increases about 30% by acetazolamide. The range of increase is consistent with the value varied with the brain functions[3),4)]. This means that we may be able to detect the change in blood volume related to the brain function by this method. We have no data, however, indicating whether we can detect such changes in a local small region of the brain using this method. Intravenously infused sodium acetazolamide increases whole brain blood flow. This may be the crucial reason why we could detect the increase of signal intensity from the brain. When the blood flow increases only in a small region, such increase in the signal may be buried in a quantization bit of a A/D converter if we use the MR signal intensity obtained from a conventional imaging method as pointed out by Kamei et al.[5]. We need further development of the hardware as well as pulse sequences of the MR signal acquisition to utilize this method for the detection of brain function.

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