NOTE

# Serial Measurement of Relative Changes in Net Magnetization I : Assessment of Its Sensitivity to Detect Brain Function Using a Low Field MR Imager

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

[1]*Department of Neurology, Emory University School of Medicine*
*Woodruff Memorial Building Suite 6000, P,O. Drawer V. Atlanta, GA30322 U.S.A.*
[2]*Department of Neurosurgery and* [3]*Radiology, Nakatsugawa Municipal General Hospital*

We assessed to what extent relative changes in net magnetization could be measured with the low field (0.043T) MR imager. By the procedure to stabilize the whole MR imager hardware, we could measure the minute relative changes of the net magnetization (less than 1%) from the forearm presumably related to blood volume change. This method may be useful to measure physiological changes of blood volume in various human tissues though we need further development of hardware to measure minute relative changes in MR signal intensity with small volume selection.

## INTRODUCTION

The proton magnetic resonance (MR) signal intensity is affected by major intrinsic factors such as proton density, relaxation times, flow perfusion, diffusion and tissue temperature. Net magnetization varies with the proton density. Therefore, MR signal may be proven as useful tool if it is ascertained that proton density in a tissue alters in accordance with changes in tissue blood volume. Because tissue blood volume is directly related to tissue blood perfusion[1)], we would postulate to enable to assess time-dependent changes in tissue perfusion from serial measurements of MR signal intensity.

When regional blood volume increases by 7% in the brain with its functional change, we can estimate the net magnetization of the region will increase by up to 0.3% based on our estimation. Thus we may be able to assess functional aspect of the brain using measurement of net magnetization if we can measure the change at the order of 0.1%. This report is designed to assess the sensitivities to detect such a minute change in MR signal presumably related to tissue blood volume.

Keywords : magnetic resonance imaging, net magnetization, MR signal intensity, serial measurement, blood volume

## METHODS

We measured the changes in the FID intensity to assess relative change in net magnetization from the forearm of a healthy volunteer during compression with a blood pressure cuff at 30 mmHg. Simultaneously, we measured the time course of the relative change in the tissue blood volume at the tip of the index finger.

The FID signals were obtained by 0.043T permanent magnet MR imager (FONAR QED 80 alpha ; Melville, New York) with the transmit-receive head coil. In order to attain stabilized static magnetic field strength and to increase signal to noise ratio, both gradient and shim coils were electrically disconnected from the power supplies and grounded. Thus we made no volume selection.

The RF excitation pulse was applied to the forearm placed in the head coil. The specifications of the head ciol dimension are ; 250mm in its diameter, 125mm in depth of the element and solenoid in coil type. The repetition time was determined to get practically sufficient $T_1$ relaxation of major tissues in the forearm. The pulse sequence used in this experiment is shown in Fig. 1.

The FID intensity was calculated from the areas of 3 cycles of output signal from the phase detector with DC offset evaluation. The stability of the signal intensity is evaluated by taking repetitive FID measurement of the 10mmol $NiCl_2$ solution phantom before the *in-vivo* experiment. We started the experiment when the coefficient of variance in the FID intensity from the forearm was around 0.1% for 40 seconds.

The relative change in tissue blood volume at the tip of the forefinger were measured with a blood volume meter (Biomedical Science Co. Ltd. ; Kanazawa, Japan). Briefly, the absorption of near-infrared light (about 800nm) was measured in the reflection mode.

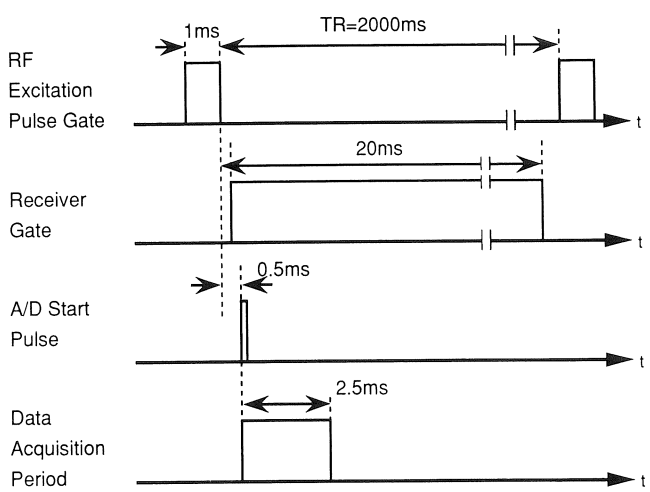


**Fig.1.**
The pulse sequence diagram
FID signals were obtained with the parameter setting shown in the diagram. TR (2000ms) was determined to get practically sufficient $T_1$ relaxation of major tissues and blood in the forearm with the low field NMR.

Received May 15, 1992 ; revised January 11, 1993
Correspondence in Japan : M.Furuse, Nakatsugawa Municipal General Hospital, Komanba, Nakatsugawa City, 508

This wave length is the isosbestic points of oxy-and deoxy-hemogrobin. The total volume of arterial and venous blood in the tissue then could be calculated by applying the Beer-Lambert Law[2]. Because the absorption of the tissue without blood is constant, we could assess the relative changes in the blood volume of the finger tip.

## RESULTS AND DISCUSSION

Time course for the relative change in the FID intensity from the forearm and for the tissue blood volume at the tip of the finger during compression of the arm are shown in Fig. 2. The former incresed by up to 1% from the initial value in 20 seconds, whereas the latter increased by about 10%.

The changes in blood volume are plotted as the FID intensity at intervals of 2 seconds. The FID intensity increased significantly (larger than mean+2SD of the values before compression) being correlated with the blood volume. Fig. 3 shows the correlation between the increased FID intensity and the blood volume. The coefficient of correlation was 0.916 and $p<0.001$.

Various factors cause changes in the MR siagnal intensity, as they are listed in the begining of the introduction. The increase in FID intensity from the forearm during compression of the arm is considerd to be caused by an increase in proton density in the tissue because of the following considerations.

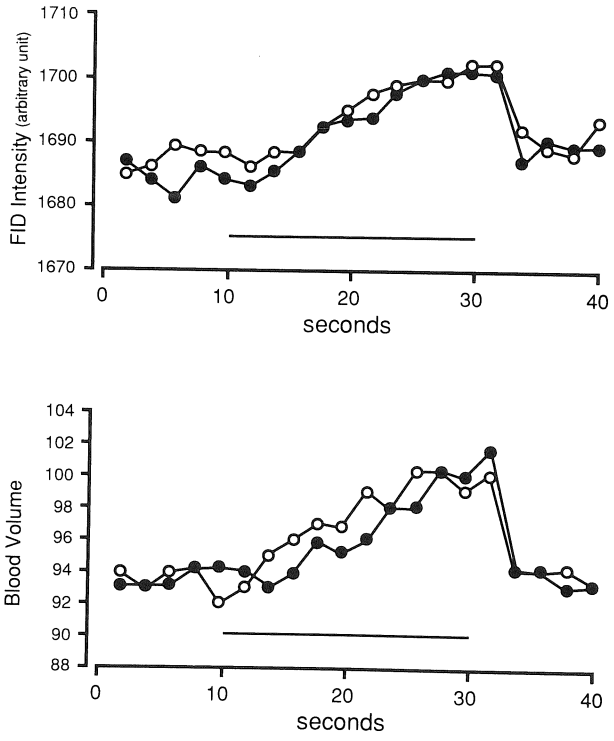


Fig.2.

Relative changes in FID intensity from the forearm (a) and in the tissue blood volume (b) at the tip of the forefinger when the arm was compressed with a blood pressure cuff at 30mmHg. The results show good correspondence between the two values. Data are plotted in arbitrary units at intervals of 2s. Bars beneath the plotted data show the period of compression.

Data acquisition series (serial 20 times) were performed twice to determine reproducibility.

Firstly retention and congestion in microcirculation in the excited site is considered to cause an increase of proton density. Secondly, the acquired signals in the experiment are considered to be proton density weighted with insignificant effect from relaxation times. Because, the TR determined to be 2000ms is longer than 3 times of major tissues and blood $T_1$s at this low static magnetic field, and the data acquisition time within 2.5ms initiated after 0.5ms delay from the excitation pulse is short enough to neglect tissue and blood $T_2$ effects. Further the tissue temperature is thought to be elevated by the venous retention that decreases the FID intensity.

Our measurements, however, may not indicate the detection of the changes in net magnetization related to only blood volume. There may be an increase in extracellular fluid volume associated with an increase in blood voume. This should also increase in the FID intensity, and to what extent can not be determined with this method. The major import of our results, however, is that we can measure the minute (less than 1%) change in MR signal intensity which is presumably related to tissue blood volume without employing any post processing such as a subtraction method.

To be able to show the extraordinary minute change in FID intensity, stabilization of the whole MR hardware system was the cardinal procedure. That was accomplished mainly by suppressing the time-related power drift for the system and the room temperature drift particularly where the transmitter had been set up.

The clinical application of this method depends on how small a region of interest can be used to measure the MR signal intensity with enough sensitivity to assess blood volume change.

Already Kamei et al.[3] proposed a method to detect the laterality of the cerebral function. Their results have proved that MR signals could be used to measure cerebral function. Our method mentioned would be another

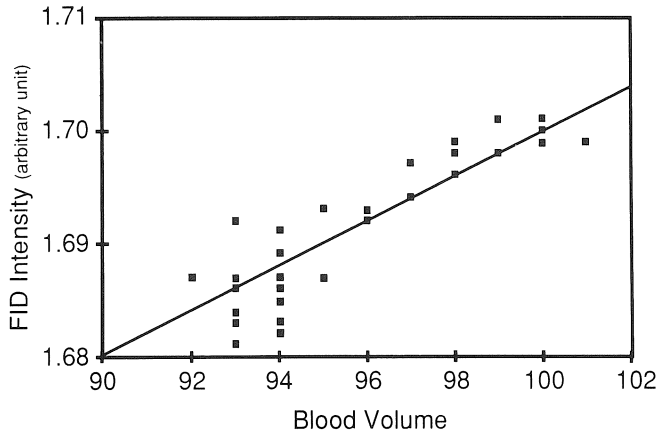


Fig.3.
Correlation between the increased FID intensity and the blood volume. The coefficient of correlation was 0.916 and $P<0.001$.

approach to measure physiological changes in tissues though we need further technical development to measure minute changes in MR signal intensity with small volume selection.

## REFERENCES

1) Weiss HR, Buchweitz E, Murtha TJ, Auletta M : Quantitative regional determination of morphometric indices of the total and perfused capillary network in the rat brain. Circ Res, 51 : 494-503, 1982.
2) Chance B, Leigh JS, Miyake H, et al. : Comparison of time-resolved and-unresolved measurements of deoxyhemoglobin in brain. Proc Natl Acad Sci USA, 85 : 4971-4975, 1988.
3) Kamei H, Katayama Y, Yokoyama H : A non-invasive method to detect the difference in functions of cerebral hemispheres by "differential NMR". in ; Microcirculation-An update vol. 1, ed. by Tsuchiya M, Asano M, Mishima Y, Oda M, Elsevier Science Publishers B. V., The Netherlands, 1987. pp417-420.