Dynamic Susceptibility Contrast Magnetic Resonance Images 를 이용한 뇌혈류량 지도 구성

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Cerebral Blood Volume Mapping from Dynamic Susceptibility Contrast Magnetic Resonance Images

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ABSTRACT

Recently, there has been growing interest in the assessment of physiological parameters on brain perfusion that provide more information than pure morphologic diagnosis. Quantification of parameters that characterize cerebral micro-circulation with magnetic resonance imaging is of great relevance for clinical application. We determine the local tissue concentration by exponential relationship between the relative signal reduction $S(t)/S_0$ and local tissue concentration of contrast material $C_m(t)$ in dynamic susceptibility contrast enhanced MR imaging. And then we made relative regional blood volume map by calculating the area under the measured concentration-time curves $C_m(t)$ during first pass of paramagnetic contrast material as a preliminary step for perfusion map. These images make it possible to compare the rCBV in different brain regions in one individual at a time. We have it in contemplation to obtain arterial and brain signal time curves simultaneously to make absolute rCBV and perfusion (rCBF) map. These maps may provide the method of comparative investigations of different patients having strong variation in AIF.

INTRODUCTION

Several research groups have investigated possibilities for measuring regional cerebral blood volume (rCBV) by MR imaging [1]. They exploited the susceptibility effect of gadopentetate dimeglumine after a bolus injection using the echo planar technique for imaging. While passing through the capillary network, a short bolus of contrast material produces local magnetic field inhomogeneities that lead to a reduction in the transverse relaxation time T2* of the tissue. This susceptibility effect can be recorded by a series of rapid T2* weighted images .Up to now, positron emission tomography has been the most widely used method of functional imaging. However, its disadvantages are poor spatial and temporal resolution and patient exposure to ionizing radiation. Dynamic susceptibility contrast enhanced imaging techniques offer the unique possibility of combining the good spatial resolution of MR imaging with the ability of PET to assess tissue micro-circulation [2]. Therefore, as a preliminary step for making absolute perfusion map to express the regional cerebral blood flow at a sight, we made a tool to obtain a relative rCBV map from dynamic susceptibility contrast enhanced images.

MATERIAL & METHOD

The rCBV(regional Cerebral Blood Volume) represents the amount of blood in a given volume of tissue. It can be determined by calculating the area under the measured concentration-time curves $C_m(t)$ and normalizing it to the integrated AIF(t), arterial input function, and the density of brain tissue(ρ=1.04g/ml) after antecubital vein bolus injection of paramagnetic contrast material.

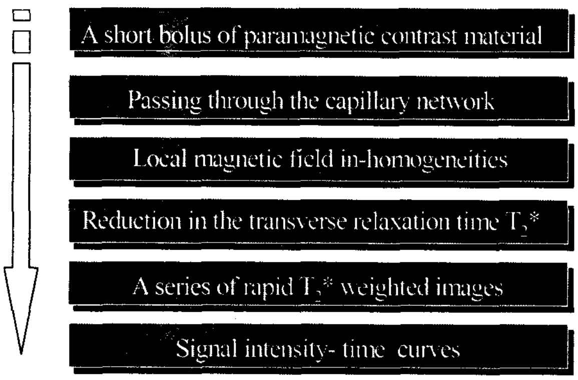
$$rCBV = \frac{k}{\rho} \cdot \frac{\int Cm(t)dt}{\int AIF(t)} \qquad (1)$$

Where k is correction factor taking into account the difference of hematocrit in vessels. Even though simultaneous measurement of the AIF(t) and the concentration-time curve in tissue are thus necessary to determine the absolute values of the rCBV, we assume a constant value for the whole brain without knowing the area under AIF curve. This makes it possible to obtain relative rCBV values. We made relative regional blood volume map preliminarily.

We determine the local tissue concentration by exponential relationship between the relative signal reduction $S(t)/S_0$ and local tissue concentration of contrast material $C_m(t)$.

$$C_m(t) = -\frac{k}{TE} \cdot \ln\left(\frac{S(t)}{S_0}\right) \qquad (2)$$

MR imaging acquisition protocol is as shown in Table1. Figure 1 shows the process to obtain dynamic susceptibility contrast magnetic resonance images. We calculated relative rCBV from 58 dynamic images in each pixel using equation (1). And then we made a map pseudo-colored with rCBV values. From this map we can observe the regional blood volume over the whole image at a glance.



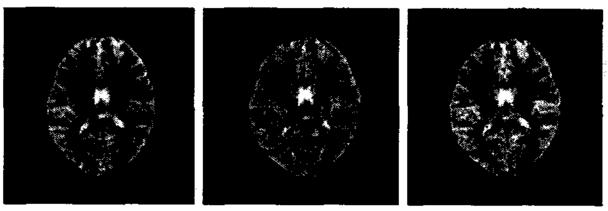
[Figure 1] Process to obtain dynamic susceptibility contrast magnetic resonance images.

Susceptibility weighted (T2* weighted) MR image
Sequence : EPI
FOV 25cm
acquisition matrix 128x128
58 dynamic images at the same(single) anatomical level
Bolus administration after acquisition of 5th image
Acquisition time of each image : 0.7sec

[Table 1] MR imaging acquisition protocol

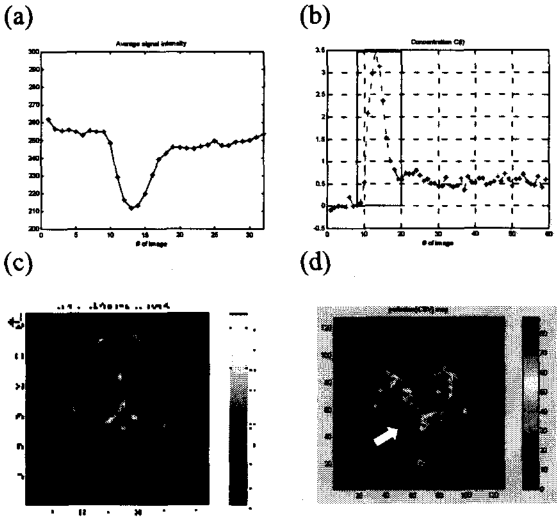
RESULTS

We made relative regional blood volume map by calculating the area under the measured concentration-time curves $C_m(t)$ during first pass of paramagnetic contrast material.



(a) (b) (c)

[Figure 2] Susceptibility contrast material - enhanced MRI (T2* weighted images) (a) 2nd image : Before bolus injection (b) 14th image : maximum decrease of signal intensity. (c) 25th image : After first pass of paramagnetic contrast.



[Figure 3] (a) Average signal intensity variation at dynamic susceptibility weighted MR images. (b) Tissue concentration calculated from exponential relationship between the relative signal reduction $S(t)/S_0$ and local tissue concentration of contrast material $C_m(t)$. (c) rCBV map of normal volunteer. (d) rCVB map shows decreased perfusion at tumor region of brain (arrowhead)

DISCUSSION

In this study we made relative regional blood volume map with the assumption that the area under the AIF has the same value in all the region of the brain as a preliminary step to obtain absolute perfusion map. Even though these images make it possible to compare different brain regions in one individual at a time, these can not provide the method of comparative investigations of different patients because of a strong inter-individual AIF variation. Therefore we have it in contemplation to obtain arterial and brain signal time curves simultaneously and then to make absolute rCBV and perfusion(rCBF) map.

REFERENCES

[1] Thomas Hacklander, Jurger R. Reichenbach, Matthias Hofer, Ulrich modder, Measurement of Cerebral Blood Volume via the Relaxing Effect of Low-Dose Gadopentetate Dimeglumine during Bolus transit, Am J Neuroradiol 1996;17:821-830

[2] Kartin A. Rempp, Gunnar Brix, et al. Quantification of Regional Cerebral Blood Flow and Volume with Dynamic Susceptibility Contrast-enhanced MR Imaging, Radiology