Measurement of Cerebral Blood Flow in Dogs: Comparison of Magnetic Resonance Imaging using $H_2{}^{17}O$ with Positron Emission Tomography using $H_2{}^{15}O$

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Introduction

MRI has become a useful tool for the diagnosis of stroke. Especially diffusion weighted imaging (DWI) has become recognized as a valuable method to detect early ischemic damage. For the measurement of local cerebral blood flow (LCBF) by MRI, the several techniques has been evaluated, such as the perfusion method (PWI) using Gd or iron contrast agent or the endogenous arterial spin labeling technique. Furthermore, a number of methods using a stable isotope of oxygen (^{17}O) as a MRI contrast agent have also been reported, and, generally, two main method has been examined, one is proton detection technique based on the T_2 shortening effect of ^{17}O (1-3), the other is ^{17}O direct detection technique (4). The former technique would have an advantage for its higher spatial resolution and its higher availability to conventional MRI equipment. Using this technique, it has shown that T_2 of brain is shortened and the stroke area is distinguished using MCA occlusion animal model after i.v. injection of $H_2{}^{17}O$ (1), and also that the increase of LCBF can be imaged by CO_2 inhalation in normal cat (3).

It has not been shown however that the LCBF measurement by $H_2{}^{17}O$ using MRI gives appropriate LCBF values compared to other methods. To confirm this, the comparison of LCBF between $H_2{}^{17}O$ MRI and $H_2{}^{15}O$ PET was performed with same imaging protocol in dogs which the blood circulation hemodynamics were carefully controlled.

Materials and Methods

Animals: Beagle dogs, weighing 5kg, were anesthetized with 1-2 % halothane in mixed gas ($N_2O : O_2 = 3$ to $4 : 1$); after tracheal intubation, they were paralyzed with pancronium, and were mechanically ventilated with an animal ventilator. A catheter was inserted into femoral vein for $H_2{}^{17}O$ injection, and another catheter was introduced into femoral artery for blood sampling. Blood pressure, heart rate, oxygen saturation rate, blood pH, $PaCO_2$, PaO_2, and end tidal CO_2 concentration were monitored. $PaCO_2$ was controlled to 20, 30, 40, 60 mmHg by 2-4 % CO_2 inhalation or hyperventilation in order to obtain different CBF level. An injection of $H_2{}^{17}O$ or $H_2{}^{15}O$ was done after all the reading of above monitoring had become stable.

MRI: Imaging was performed on 3T MRI (General Electric, Milwaukee, WI) using a standard quadrature head coil. MRI was performed using fast spin echo (FSE; TR/TE=3000/120ms, ETL=64, number of slices=5, slice thickness=4mm, BW=31.25kHz□FOV=160×160mm, matrix=256×128, scan time=15sec). $H_2{}^{17}O$ (40atm%, 2mL/kg) was injected at a constant speed for 40 seconds. MRI images were acquired at pre and post injection for every 15 sec for 5 min and for every 1 minute thereafter up to 20 min post injection. Arterial blood was sampled with time during the imaging and ^{17}O concentration in arterial blood was measured by NMR spectrometer (Unity plus 500, Varian inc. Palo Alto, CA)

PET; Images were obtained using animal PET (SHR-7700; Hamamatsu Photonics K. K., Japan). $H_2{}^{15}O$ (23mCi/15mL) was injected as same as the procedure as MRI. PET images were acquired from immediately after the injection for every 10 sec for 3 min and thereafter for every 30 sec up to 5 min post injection. Arterial blood was sampled with time during the imaging, and the radioactivity was measured.

CBF analysis: The MR signal intensity changes in the brain were converted to the $H_2{}^{17}O$ concentration images according to the method by Arai (3), and CBF map was calculated by the Look-up Table method from the arterial input. CBF map from PET images was also calculated by same manner. Region of interest analysis was performed at several areas in both CBF maps by MRI and PET.

Results

The representative images of $H_2{}^{17}O$ MRI and $H_2{}^{15}O$ PET have shown in Fig.1. LCBF map by $H_2{}^{17}O$ MRI was acquired with much higher spatial resolution. The LCBF value by $H_2{}^{17}O$ MRI was almost equivalent to the one by $H_2{}^{15}O$ PET, and showed quite good linearity to the $PaCO_2$ change, i.e. from lower CBF to higher CBF range, as shown in Fig.2.

Discussion

Above results proved that $H_2{}^{17}O$ MRI using present protocol could provide appropriate LCBF measurement, and that its LCBF value is comparable to the one by $H_2{}^{15}O$ PET among the wide range of LCBF. This suggests that $H_2{}^{17}O$ MRI using widespread MRI equipments could be a good alternative of $H_2{}^{15}O$ PET, which is highly specialized equipment. Though the high cost of production of $H_2{}^{17}O$ is only problem of this technique, this study strongly suggests that $H_2{}^{17}O$ as a MRI contrast agent is ready to available for accurate LCBF measurement in stroke patients.

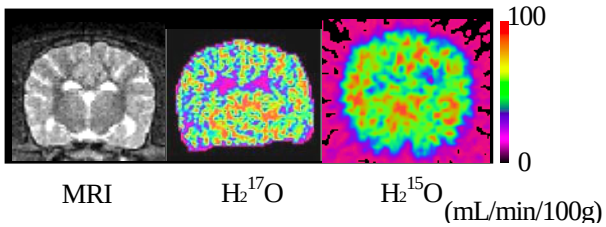

Fig.1 Comparison of the representative images of $H_2{}^{17}O$ MRI and $H_2{}^{15}O$ PET comparing the anatomy image by T2W MR image for virtually same position.

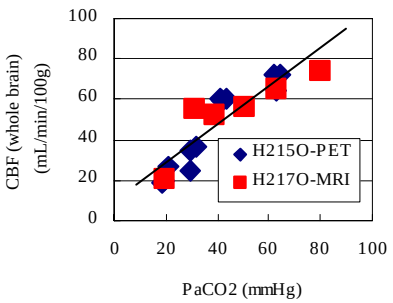

Fig.2 Comparison of CBF values by MRI and PET at different PaCO2 level.

References

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