Correction for the T2 effect of contrast agent on absolute CBV quantification using VASO

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Introduction

Absolute cerebral blood volume (aCBV) can be assessed by utilizing the signal difference of vascular space occupancy (VASO) sequence before and after injection of T1 shortening contrast agent.[1] In previous report, the T2 effect of contrast agent is proved to influence the accuracy of absolute CBV quantification using VASO.[2] Other than using extrapolation by a multi-echo sequence, we propose an alternative method to reduce the T2 effect when using relative long TE sequence. Experiments on rat model were conducted to investigate the feasibilities. Since the T2 of water and blood are distinct, correction for the intensities ratio of blood/water under such TE was also performed to substitute the physiological parameter C_b.

Materials and Methods

Using the VASO technique, the aCBV could be calculated as: $aCBV= (S_{pre}-S_{post})/(A\cdot C_b)$, where S_{pre} and S_{post} are the intensities of VASO images before and after injection of T1 shortening contrast agent, respectively. $A\cdot C_b$ is a scaling constant which equals the intensity when the pixel is full of blood. In this study, non-selective inversion recovery (IR) spin-echo EPI sequence was implemented with 14 TIs from 50 to 2650 ms to calculate pre and post contrast T1 and the $M_0\exp(-TE/T2)$, which is the initial height of IR at TI=0. The T2 effect of contrast agent was corrected by reconstruct the IR images with the pre contrast initial height $M_0\exp(-TE/T2_{pre})$ and post contrast $T1_{post}$ as the following equations:

$$SI_{pre}(TI) = \left[M_0 \times \left(\exp\left(-\frac{TE}{T2_{pre}}\right)\right)\right] \times \left(1 - 2 \times \exp\left(-\frac{TI}{T1_{pre}}\right)\right)$$

$$SI_{post}(TI) = \left[M_0 \times \left(\exp\left(-\frac{TE}{T2_{post}}\right)\right)\right] \times \left(1 - 2 \times \exp\left(-\frac{TI}{T1_{post}}\right)\right)$$

$$SI_{post,modified}(TI) = \left[M_0 \times \left(\exp\left(-\frac{TE}{T2_{pre}}\right)\right)\right] \times \left(1 - 2 \times \exp\left(-\frac{TI}{T1_{post}}\right)\right)$$

In this study, five normal male Sprague-Dawley rats were anesthetized with 1.5% Isoflurane and scanned in a 4.7T animal MRI scanner (Bruker Biospec 47/40). Non-selective inversion recovery spin-echo EPI sequence was implemented with 14 TIs from 50 to 2650 ms to calculate T1 map on a 4.7T animal MRI system (Bruker Biospec 47/30, Germany). Imaging parameters are as follows: TE/TR= 48.79/6000 ms, FOV: 32 mm, matrix: 64x64, single slice, slice thickness 1.5 mm. 0.3 ml of Gd-DTPA (Magnevist) was injected manually from tail vein. A tube containing saline was fixed on the surface coil for the reference of scaling constant $A\cdot C_b$.(shown in Fig. 1) One ml of arterial blood was drawn from three rats for additional phantom experiments with the same sequence and parameters, and deriving T1 of rat blood and a modified scaling constant $C_b \exp[-TE(R_{2blood}-R_{2water})]$ at TE 48.79 ms. Then, pre and post contrast IR images at the nulling time of rat blood were subtracted. The aCBV map was calculated by $(S_{pre}-S_{post,\ modified})/\{A\cdot C_b \exp[-TE(R_{2blood}-R_{2water})]\}$.

Results and discussion

Fig. 2 showed the T1 fitting result of one pixel. It is noted that the initial heights was lower in post contrast IR curve. This T2 effect was then eliminated by generating the S_{pre} and $S_{post,\ modified}$ with the TR as infinite long and the Nulling TI as 1130 ms, which was calculated from the measured T1 of blood as 1630 ms. Modified scaling constant $C_b \exp[-TE(R_{2blood}-R_{2water})]$ was also measured in our phantom experiment as 0.43±0.04. After obtaining the A value from the mean intensity in water tube, the aCBV map was generated as shown in Fig. 3. In conclusion, we successfully implemented our proposed method for absolute quantification of CBV value on rat model. The systematic error of T2 effect could be reduced by an alternative method. This method could be practical on small animal scanner while TE of spin echo EPI cannot be reduced to insignificant values. In addition, when using longer TE, the intensities ratio between water and blood will not be equal to C_b and modification was applied since the T2 of water and blood are different.

References 1. Lu H et al. MRM 54:1403-11 (2005).. 2. Uh J et al. MRM 61:659-67 (2009).

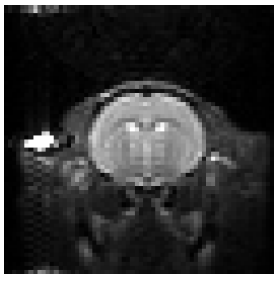

Fig. 1. A IR EPI of rat axial slice is shown. Note that a water tube with high intensities is shown in the left side. It is used as the reference constant “A”.

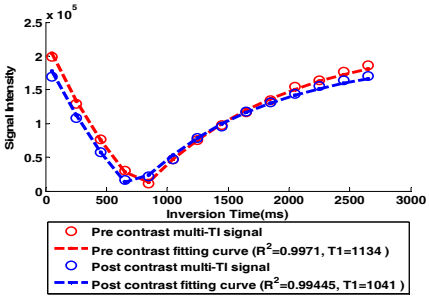

Fig. 2. The IR EPI intensities at 14 TIs are used to calculate the T1 and initial height. Note that the blue dash line has a lower initial height because of the T2 shortening effect of Gd-DTPA.

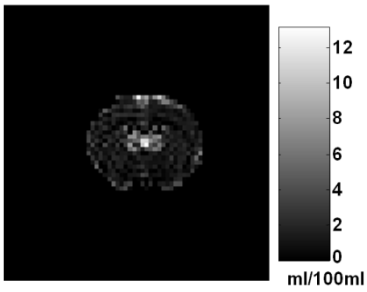

Fig. 3. A calculated absolute CBV map on rat axial slice.