Absolute Cerebral Volume Quantification by Vascular Space Occupancy Technique on Rat Model with Optimized Inversion Time

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Purpose

Recently a new approach to measure the absolute cerebral blood volume (aCBV) has been reported by utilizing the signal difference of vascular space occupancy (VASO) sequence before and after injection of T1 shortening contrast agent.[1] In spite of possible variation of the T1 of blood may exists, a fixed inversion time (TI) was used in the previous report. In this study, the information of relative cerebral blood volume (rCBV) from dynamic susceptibility contrast (DSC) imaging is included to optimize the TI for the aCBV quantification by VASO method on a rat model.

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. Instead of using single fixed TI, we use multiple TIs to calculate the T1 value pixel-by-pixel. DSC images were acquired between two VASO sequences while injecting the Gd-DTPA (Magnevist, Bayer Schering) bolus. After calculating the DSC rCBV map by accumulating the area under the concentration-time curve of the first pass of bolus, the S_{pre}-S_{post} of different TI was correlated to the rCBV value. Therefore, an aCBV map can be generated by the VASO method using optimized TI with highest R square value between rCBV and S_{pre}-S_{post}.

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. A surface coil was used, and the sensitivity of coil was normalized by acquiring an identical image from a fixed volume coil. Four male Sprague-Dawley rats were anesthetized using isoflurane or alpha-chloralose. Gd-DTPA bolus was injected manually from tail vein. A tube containing saline was fixed on the surface coil for the reference of scaling constant $A\cdot C_b$, since both ventricles and blood vessels are difficult to be measured without partial volume in rat brain images when using the method mentioned in previous report.[1] The $A\cdot C_b$ is also measured by another phantom experiment by drawing rat blood from tail artery.

Results

An aCBV map on the axial slice at anterior commissure was shown in figure 1. The R^2 value of two-fold down-sampled VASO aCBV map and DSC rCBV map were calculated as a function of TI and shown in Fig 2a, in which the optimized TI is shown at 1118 ms with a highest R2 0.67. It can be noted that the R^2 decreased significantly when the TI deviated from the optimized value. The scatter plot of VASO aCBV and DSC rCBV at the optimized TI is also shown in Fig 2b with highly correlation. The optimized TIs of four experiments are 1111.8±101.2 ms with R2 as 0.71±0.037, and the mean aCBV is 5.51±1.30 ml/100ml tissue, which is close to previous report of aCBV value at 4.77 ml/100ml tissue.[2]

Discussion and Conclusion

In this study, we successfully show the feasibility of generating aCBV maps using VASO techniques with correlation to the DSC measured relative values on a rat model. We use the DSC rCBV map as an optimization reference because it's a robust method with high contrast to noise ratio. Although the absolute quantification can also be accomplished by the DSC method itself, the VASO method has the advantage of practicability without the complicated procedures such as finding and deconvolving an arterial input function, which is required for the absolute quantification of DSC method and possibly introduce systematic errors. The optimized TIs are not a fixed value for different experiments. Therefore, it is also shown here that the R^2 of CBV value could be decreased significantly when using fixed TI depart from the optimized one. Therefore, our proposed modified VASO method has the potential to increase the accuracy of aCBV quantification, which should be beneficial for longitudinal monitoring of brain perfusion level.

References:

1.Lu H et al. MRM 54:1403-11 (2005). 2.Sandor P et al. Life Sci 39:1657-65 (1986).

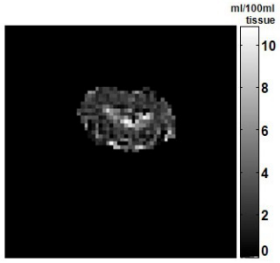

Fig 1 absolute CBV map of a rat axial slice

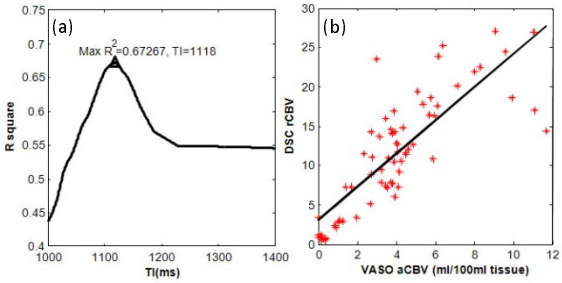

Fig 2 (a) the R2 between VASO and DSC CBV as a function of TI. (b) the scatter plot of VASO absolute CBV and DSC relative CBV on the optimizationTI with R2=0.67.