Multi-Slice Absolute Cerebral Blood Volume Quantification on Animal Model Using a Hybrid Method of Vascular Space Occupancy and Susceptibility Effect of MION

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Purpose

Cerebral blood volume (CBV) is a valuable physiological parameter for brain research on animal models. In previous study, the vascular space occupancy can achieve absolute quantification of CBV.[1] However, due to using a multi-slice inversion recovery sequence, only one slice can be estimated on the exact blood nulling time. Therefore, we propose a hybrid method by which multi-slice absolute CBV maps are generated by correlating multi-slices relative CBV map by injection of MION to the single slice absolute CBV map by VASO method on the overlapped position. Utilizing the MION's characteristics of high susceptibility effect and long half-life, the feasibility of acquiring high contrast to noise ratio multi-slices absolute CBV maps is studied here.

Materials and Methods

We access the CBV value by three methods and generated a multi-slices absolute CBV map by combining the information of these methods. The most popular DSC method can achieve a robust and high-contrast relative CBV map by accumulating the area under the concentration-time curve at first pass of Gd-DTPA bolus without deconvolution of the arterial input function. The signal difference of VASO image before and after Gd-DTPA injection can be calculated to an absolute CBV value by referencing the intensity of a saline tube, and the TI for blood nulling can be optimized by the correlation to DSC relative CBV. By injection of a long-half life contrast agent MION, the ΔR2 is proportional to the CBV, and a multiple slice relative CBV map can be accomplished by T2 weighted sequences.[2] Therefore, our strategy of multi-slices absolute CBV is to find the high-correlated regression line between the VASO absolute CBV and the overlapped ΔR2 relative CBV map, and then covert the multi-slices ΔR2 map to absolute CBV values. The timing diagram of VASO, dynamic susceptibility contrast imaging, and T2 weighted multi-slices images are shown as in Fig 1. The imaging parameters are as follows: 14 TIs with equal interval from 50~2650, TE/TR=48.79/6000ms, FOV 32mm, matrix 64x64, single slice spin echo EPI for VASO sequence; TE/TR=25/500 ms single slice gradient echo EPI with other identical parameters for DSC imaging while injection of Gd-DTPA; TE/TR=16.2/2500 8 slices gradient echo EPI for ΔR2 mapping by injection of MION with the 2nd slice is at the same position as other single slice images. 3 male Sprague-Dawley rats were anesthetized using isoflurane or alpha-chloralose. 0.3 ml of Gd-DTPA (Magnevist, Bayer Schering) and 20 mg/kg of MION were injected by tail vein. The R square values of the correlation of 3 methods are calculated. Besides, we also measured absolute CBV map two times by using VASO at two distinct slices and different time on one rat to validate the robustness of this hybrid multi-slice method.

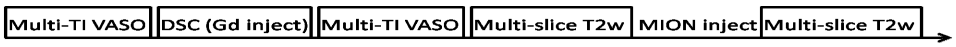

Fig 1 Timing Diagram

Results

One CBV map calculated by this method is shown in Fig 2. The scatter plot of the ΔR2 relative CBV map verses VASO absolute CBV is shown in Fig3a, and the scatter plot of the ΔR2 and DSC CBV are shown in 3b. The mean R square between absolute CBV of VASO and ΔR2 in three experiments is 0.65±0.09, and the R square between ΔR2 and DSC relative CBV is 0.87±0.01. The absolute CBV map shown in Fig 2 was measured again by VASO at a distinct slice and a new regression line was calculated to generate a new CBV map at the identical slice. The difference of absolute CBV map is shown in Fig 4. Note that the small differences shown in this figure, and it means that the proposed hybrid method can calculate robust and consistent absolute value for multiple slices at different time with only 1.3±1.03%.

Discussion and Conclusion

We proof the feasibility and robustness of measuring multi-slice absolute CBV by this proposed hybrid method. The CBV measured by 3 methods are highly correlated and it is reasonable to convert the multi-slice relative CBV to absolute values according to their regression line. Using MION has the advantage of high susceptibility effect and long half-life. Therefore, this hybrid method could be beneficial for a long time and/or longitudinal whole-brain CBV monitoring studies on animal models, such as tumor, stroke and pharmacological fMRI studies.[3]

References

1.Lu H et al. MRM 54:1403-11 (2005). 2.Mandeville JB et al.MRM 39:615-24(1998) 3.Chen YI et al. Neurosci Lett 431:23-5.(2008)

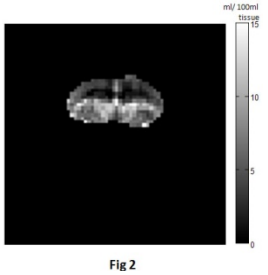

Fig 2. The CBV map of one axial slice on rat.

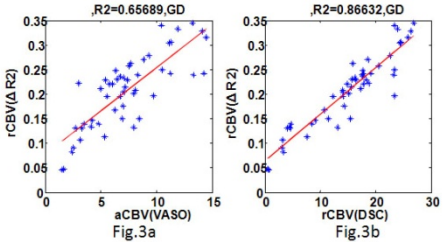

Fig 3. (a) The scatter plot of ΔR2 relative CBV and VASO absolute CBV. Note the high correlation.(b) The scatter plot of ΔR2 relative CBV and DSC relative CBV. Note the R square is about 0.866.

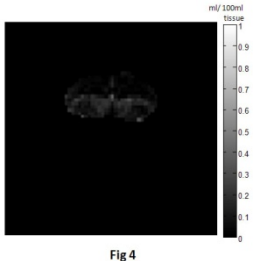

Fig 4. The difference map of absolute CBV by subtraction of Fig 2 by another multi-slice absolute CBV measurement using VASO on distinct slice at different time. Note the difference is only 1.3±1.03% from the first measurement, which means the multi-slice measurement is robust and consistent.