Calibration of ASL Quantification Based on Hypercapnia and Sensory Motor Activation

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Introduction

To evaluate the feasibilities of quantifying cerebral perfusion with dynamic magnetic resonance artery spin labeling (ASL) sequence, numerous techniques of ASL quantification have been proposed in the last several yeas[1],[3],[4]. In fMRI, the blood oxygenation level-dependent (BLOD) effect depends on the cerebral blood flow (CBF), blood volume (CBV) and metabolic rate of oxygen (CMRO2) changes. Thus, rCMRO2 maps relative to baseline can be estimated by measuring CBF and BOLD[4]. The previously studies [2],[4] shows that the positive correlations between CBF and CMRO2 changes in hypercapnia activation. In our study, we measured correlations of CBF and rCMRO2 changes not only in hypercapnia activation with breath holding (BH) but also sensory motor activation with a check board (CB) visual stumilation. For evaluating the correlation of CBV and CMRO2 changes, we applied M coefficient which is a contant and proportional to CBV. The correlations of CBF with CMOR2 and M with CMRO2 are evaluated based on CBF and M quantification. Very weak positive but non-significant correlations between CBF and rCMRO2 are observed in BH task, correlations between M and CMRO2 changes is not shown in our analysis. In CB task, both of positive correlations of CBF with CMOR2 and M are obvious. Based on those results, we confirmed that BH task increased CBF and it is not significant or weak effects to CMRO2 changes. CB task doesn't increase the GM CBF as much as BH task but CMRO2 is increased significantly due to CBF and M increasing in specified areas such as vision and motor areas.

Materials and Method

In this work, 4 subjects (30.75 ±11.7 years old) were studied at Siemens Trio 3.0T MR system. A breathing holding (BH) task was used for hypercapnia activation and a visual flashing checker board which subjects respond to with a fingerpress (CB) for sensory motor (SM) activation. CBFs were calculated in rest and activation (BH & CB) situation. For evaluating the gray matter (GM) CBF and rCMRO2 changes, we applied FreeSurfer (FS) segmentation to get the GM mask from a T1 anatomic structure image. Instead of CBV measurement, we evaluated M coefficient which is proportional to CBV. The ASL images were acquired during normal relaxed breathing initially, then during BH and CB activation in 20s ON/OFF repetition. For the image acquisition paradigm, 48 (24 controls and 24 tags) ASL images were acquired during the rest status, 148 (74 controls and 74 tags) and 184 frames (92 controls and 92 tags) images during BH and CB activation. Image parameters were a TR of 2500ms, TE of 50ms, slice thickness of 14mm, matrix size of 64x64 and FOV of 24x24(cm). For measuring M and rCMRO2, the following equation (1) and (2) proposed by T.L. Davis [3] were applied. Here, M indicates baseline tissue dHB content that can be thought of as the baseline dHB concentration, proportional to CBV. α and β are measured at 0.38 and 1.5 respectively [3]. Fh and Bh are CBF and BOLD ratios for activation versus baseline. F and B are normalized CBF and BOLD; linear normalization was used here. CBF was measured during baseline, rest and activation period with the method proposed by JJ Wong[4] , then M and rCMRO2 were calculated in rest and active status. 2 ROIs are located at left and right motor area, 2 are located at vision area and 1 is located at frontal lobe, totally 7 ROIs at each subject are used to analysis.

$$M = \frac{rB_h - 1}{1 - rF_h^{-(\beta-\alpha)}} \qquad (1)$$

$$rCMRO2 = F^{1-\alpha/\beta}\left(1 - \frac{B-1}{M}\right)^{1/\beta} \qquad (2)$$

Result and Discussion

Figure 1 shows maps of baseline and activation CBF, M, and CMRO2 in BH and CB task, and Table1 shows the % change of CBF, M and CMRO2 based on ROI analysis. The large standard deviation of ΔM and ΔCMRO2 means the variance is strong in M and CMRO2 quantified values duo to the noise which those noises is obvious at Figure 1. In BH and CB activation, respectively, CBF increased 32.39%±9.6% and 14.90%±11.13%, M increased 29.31%±18.59% and 18.77%±11.74%, CMRO2 changed by 5.67%±7.9% and 7.93%±18.54%. In the hypercapnic BH task, a weak positive correlation between CBF and CMRO2 changes was shown in our analysis results but not between M and CMRO2. In sensory motor CB task, positive correlations between CBF and CMRO2, M and CMRO2 are observed (see below).

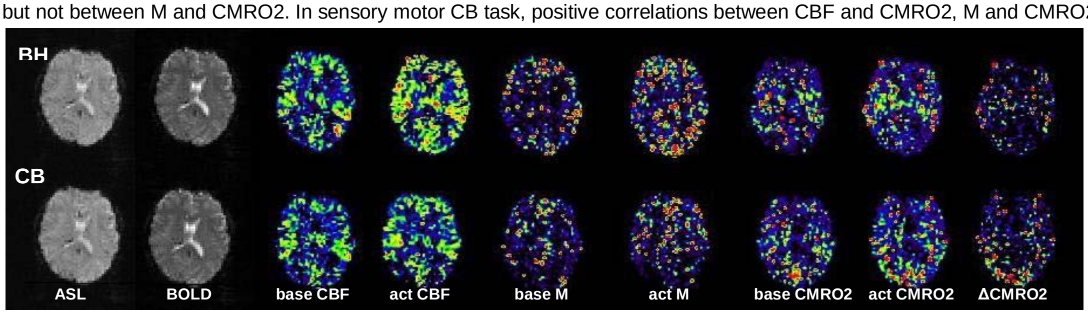

Fig.1 Functional ASL quantified maps

Tab.1 CBF, M and CMRO2 changes in BH and CB activation

	Breath Holding			Check Board		
	ΔCBF(%)	ΔM(%)	ΔCMRO2(%)	ΔCBF(%)	ΔM(%)	ΔCMRO2(%)
Subject1	16.63	3.78	4.01	6.07	4.16	2.80
Subject2	30.42	47.22	-4.75	9.06	21.55	34.98
Subject3	44.46	37.36	13.21	13.55	32.51	1.07
Subject4	38.41	28.88	10.22	30.95	16.87	-7.11
Ave	32.38±12.05	29.31±18.60	5.67±7.93	14.91±11.13	18.77±11.74	7.94±18.54

Figure 2 shows total 28 ROIs mean values distribution of ΔCMRO2 with ΔM and ΔCBF. In BH task, the correlated coefficient of ΔCMRO2 with ΔCBF and ΔM is 0.34 (p=0.09) and 0.14 (p=0.38), respectively. Thus, a weak positive correlation between CBF and CMRO2 was showed in BH activation in our study. For CB activation, the distribution are shown by Figure 3, correlated coefficients are 0.43 (p=0.056) and 0.42 (p=0.12) between ΔCMRO2 and ΔCBF, ΔCMRO2 and ΔM respectively, suggest a weak significant positive correlation between CMRO2 and CBF, CMRO2 and M in CB activation task. CBF increased 32% in BH activation study; this is a little bit lower than the evaluated value previously reported [2], due to the weak CBF change in Subject1. Noise decreasing methods should need more consideration in the future works, such as apply a Gaussian normalization instead of linear due to the noise smoothing effect in Gausian filtering.

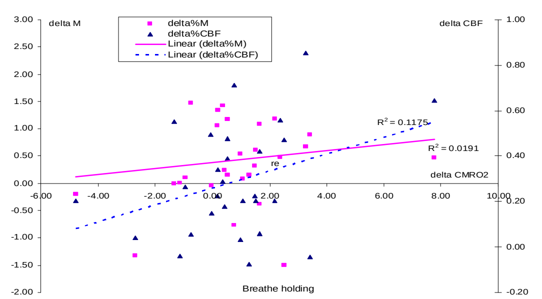

Fig2. Distribution relations of rCMRO2 and CBF, M in BH

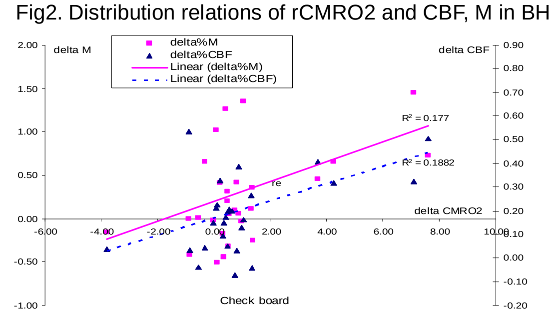

Fig3. Distribution relations of rCMRO2 and CBF, M in CB

References

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