Cerebral Blood Flow Change in One Hear Beat by CO2 Concentration using Retrospective PC MRI Measurements

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Introduction: Velocity-sensitive magnetic resonance imaging involving phase-contrast (PCMRI) techniques has been widely used in blood flow and CSF production rate [1,2]. It is noninvasive modality to quantify the blood flow and blood volume in one heart cycle with high spatial and temporal resolution. The variation of blood flow in artery is generated by systole and diastole during one cardiac cycle. Using velocity-sensitive PCMRI with retrospectively gated techniques, we can observe the velocity profile in one heart beat. Dilatation of cerebral arterioles could be induced by carbon dioxide (CO2) and breath holding. The change of cerebral hemodynamics is related with CO2 concentration [3]. In this study, we evaluated a completely noninvasive flow quantification of cerebral vessel with multi CO2 concentration in normal subject by combining quantitative PC MRI.

Method: Six normal subjects (mean age 29, range 23-37) given informed consent were scanned with retrospectively gated 2D PCMRI using a 1.5T whole-body system (Siemens Vision plus, Erlangen, Germany).. On the basis of a localizer MR angiography (MRA) slab in the sagittal plane, a 2D PCMRI slice was positioned to measure the volume flow in the left (LICA) and right internal carotid artery (RICA), basilar artery (BA), sinus rectus (SR), superior sagittal sinus (SSS) (Fig 1). 2D PCMRI measurements were performed with conventional protocol using optimal scan parameters (TR/TE= 29/7 ms; flip angel=30°; matrix size 115×256; FOV 120x240; V_enc=150 cm/sec; slice thickness=5mm.). 64 cardiac phases were acquired and rearranged with retrospective electrocardiographic gating [4] to form 32 images that represented sequential phases in a cardiac cycle. The scan time was 3 min 35 sec. Total four PC MRI scans were performed for different CO2 concentration (room air and 3%, 5% and 7% CO2 gas). Due to the response including gas exchange in ling and dilatation of cerebral arterioles, the cerebral perfusion was increased progressively and it took roughly 150 seconds to reach the steady-state hypercapnia after CO2 gas inhalation [5]. For 3%, 5% and 7% CO2 gas experiment, the PC MRI, was started at 3 min after CO2 gas inhalation. Quantitative blood flow values were calculated in the manually defined ROI regions according to the methods proposed by Huang et al. [2].The velocity profile and blood volume of each vessel in one heart beat was observed for different CO2 concentration.

Results: Figure 2 depicted the mean blood flow of five vessels in one cardio cycle from all subjects during the experiment. The blood flow was proportionally increased with CO2 concentration. Figure 3 showed the blood volume change under all four different concentrations of CO2.

Discussion: According our results, the blood volume per heart beat was increased about 0.6, 1.2, 2.4 ml as 3, 5 ,7% CO2 in RICA and LICA, 0.4, 0.8, 1.6 ml in BA, 0.4, 0.7, 1.8 ml in SR, and 0.7, 1.4, 4.4 in SSS. In addition, the blood velocity curve shows the prolonged plateau as 5% and 7% CO2 in three arteries. It is concluded that the PCMRI with retrospectively gated techniques allowed for the detection of complete assessment of blood flow and volume with multi CO2 concentration. It could be a potential method to evaluate more details in cerebrovascular disease.

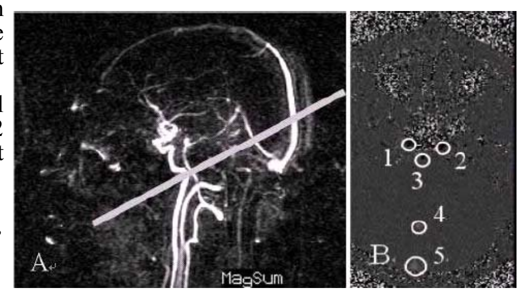
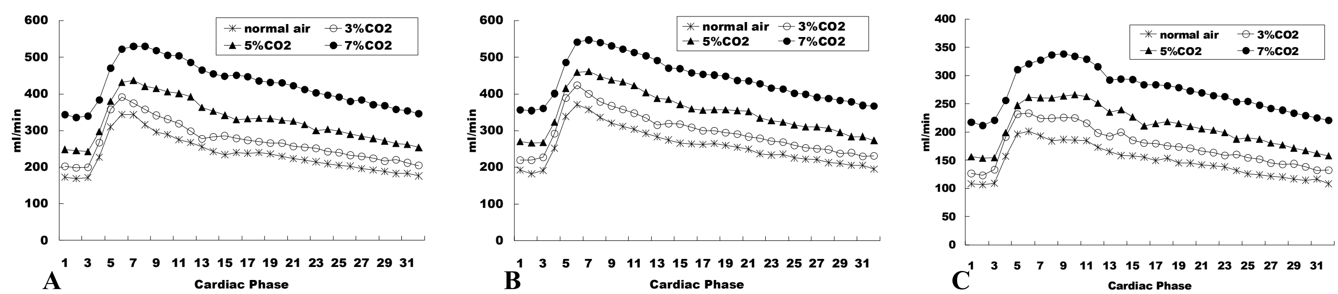


Fig1. (A) Sagittal localizer MRA. (B) Phase image with ROI (1) RICA (2) LICA (3) BA (4) SR (5) SSS.



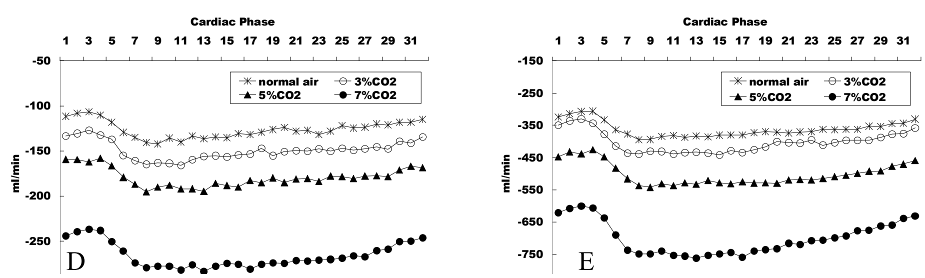


Fig2. (A) right internal carotid artery , RICA (B) left internal carotid artery, LICA (C) basilar artery,BA (D) sinus rectus,SR (E) superior sagittal sinus, SSS. The mean blood flow in one cardiac cycle as a function of time for the six subjects included in this study.

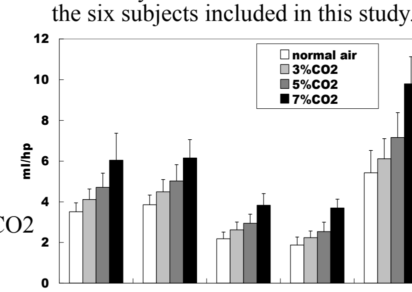


Fig3. The blood volume change in one cardiac cycle under different CO2 concentrations for the six subjects included in this study.

Reference:
1. Szolar DH, et al., JMRI. 1996 Jan-Feb;6(1):78-89.
2. Huang TY, et al., Radiology. 2004; 233, 603-608.
3. Juan CJ, et al, Proc. ISMRM 2006; 541.
4. Nitz WR, et al, Radiology. 1992; 183:395-405.
5. Liu YJ, et al, AJNR. 2007; 28:1009 –14.