Estimation of CBV using a single scan approach

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Introduction:

A number of methods have been proposed for the estimation of cerebral blood volume (CBV) using magnetic resonance imaging, including both steady state and dynamic imaging based techniques. These techniques require the acquisition of multiple sets of images for the dynamic contrast approaches and images prior to and after the injection of contrast agent for steady state methods. For both these techniques, it is difficult to obtain repeated independent measures of CBV, since in both methods, the baseline has been shifted due to the addition of contrast agent. Recently, utilizing the signal model proposed by Yablonskiy and Haacke [1], Yablonskiy [2] proposed the use of a multi-echo sequence to obtain direct susceptibility volume estimate, and demonstrated good agreement with the anticipated results in a phantom study. We explored the utility of this technique using an experimental hypercapnic animal model using MION as the contrast agent to highlight the entire vascular pool.

Methods:

The Institutional Animal Care Committee approved all protocols. The femoral artery was cannulated in each of six male Long Evans Rats (350 +/- 25 grams). The animal was ventilated with different gas mixtures (carbogen (3% CO2) and medical air) through a tracheotomy. Pancuronium bromide (1 ml/kg) was utilized to prevent the animal's own respiration drive. MION (CMIR-47) was injected at a dose of 10 mg/kg, and supplemented (1 mg/kg) at the end of each scan. Arterial pCO2 content was measured using a blood gas analyzer. Animals were imaged on a Siemens 3.0T Allegra, with a custom birdcage coil (4.3 cm diameter). A multi-echo sequence with a SE-TE of 10msec and 22 additional gradient echoes following the SE was used to acquire 23 images. Hereafter, this sequence will be referred to as SEFID. A ΔTE of 4.0 msec was used between two adjacent echoes. Imaging parameters was as follows: TR=1.5 sec, 10 averages, FOV=43 x 43 mm with a matrix size of 64x64 and 1 mm slice thickness.

Each manipulation consisted of adjusting the air/carbogen ratio at a constant total flow rate (600 ml/min) then waiting 5 minutes for steady state conditions. Blood draws were performed immediately after each acquisition. Three to four manipulations were performed for each animal. A region of interest encompassing both hemispheres was drawn on the image slice from each animal. Based on the signal model, the CBV is the difference between the actual acquired SE signal and the signal extrapolated from the R2* decay back to the time of the SE. In other words, the log of the signal was fit to a curve where ln S(t)=a – R2*(t) using the last 15 points of the decay curve. CBV is then equal to the difference between extrapolated and actual signal, or CBV= a – ln S(0), seen also in Figure 1.

Results

Mean baseline pCO2 was 45.7 +/- 5.9 with CBV of 2.2 +/- 0.88%. CBV demonstrated a linear relationship with the pCO2 of the blood, with r = 0.77 for all CBV and pCO2 measurements (Figure 2). For individual animals, the lowest r-value was 0.90 for the PCO2/CBV relationship.

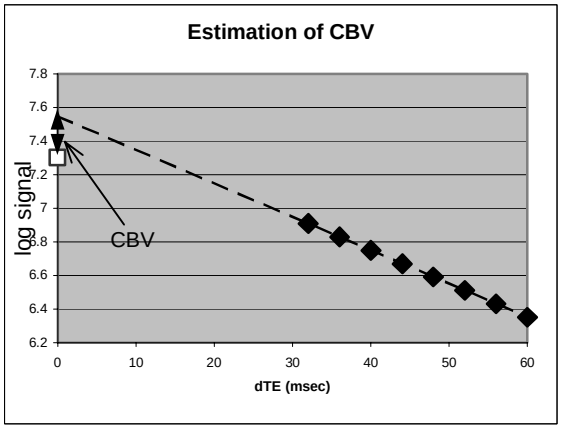

Figure 1. CBV estimates are performed by extrapolating from the dTEs back to the spin echo signal. The difference (arrow) between the extrapolated signal (dotted line) and the actual signal (square) represents CBV

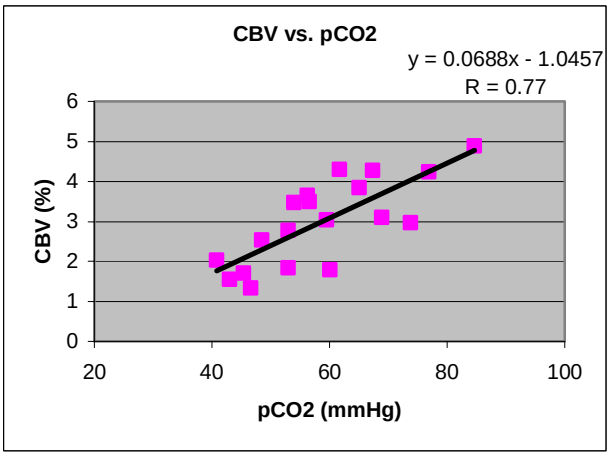

Figure 2. Plot of CBV versus pCO2 for all six animals. An r value of 0.77 was obtained for the linear regression.

Discussion and Conclusion

We have demonstrated that quantitative estimates of CBV can be repeatedly obtained with a model-based approach that does not require acquisition of multiple sets of images or baseline scans. With experimental hypercapnia, a linear relationship between CBV and pCO2 is obtained, in good agreement with results reported in the literature[3] and consistent with the anticipated physiological responses under hypercapnic conditions. In addition, the long half-life of MION offers the ability to repeatedly acquire CBV. MION was used as a susceptibility source to highlight the entire brain vasculature to provide comparison with steady state and dynamic techniques. Additional studies are currently underway to exam the efficacy of this approach under other pathophysiological conditions.

References: 1. Yablonskiy DA and Haacke EM. MRM. 1994 Dec;32(6):749-63. 2. Yablonskiy DA, MRM. 1998 Mar;39(3):417-28. 3. Lin W, et. al. JCBFM. 1999 Aug;19(8):853-62.