Error propagation in CMRO2 derivations using CBF and BOLD imaging

H-W. Chung[1], and W. Wu[2]
[1]Electrical Engineering, National Taiwan University, Taipei, Taiwan, Taiwan, [2]National Taiwan University

Introduction

A model to derive the cerebral metabolic rate of oxygen (CMRO2) from measurements of the cerebral blood flow (CBF) and the BOLD signals under hypercapina has been proposed [1]. With simultaneous BOLD imaging and CBF estimation using arterial spin labeling (ASL), the model has further been adopted to examine the metabolic connections in the default mode network using resting-state CMRO2 derivations [2]. Since the CMRO2 derivations involve computations based on ASL and BOLD imaging experiments which are both known to exhibit relatively weak contrast-to-noise ratio (CNR), the reliability of instantaneous CMRO2 derivation without performing multiple signal averaging remains unclear. The purpose of this study is therefore to investigate the issues error propagation in CMRO2 estimations under different CNR.

Materials and Methods

Resting-state CBF images from two healthy subjects were acquired with the ASL technique at 3.0 Tesla. Regions-of-interest from the visual cortex and the cingulated cortex were drawn to obtain typical CBF-time curves. Instantaneous CMRO2 values were simulated using Gaussian-distributed random numbers, pre-specified triangular waveform, and 3-ON-4-OFF boxcar blocks, treated as true values. BOLD signals were then derived from the CBF and the CMRO2 time series using the model described in [1,2] with M = 2.2, alpha = 0.38, and beta = 1.5. Racian noise was added to the CBF and BOLD data at various CNR, followed by re-derivation of CMRO2 back from CBF and BOLD data. In this manner the behavior of the derived CMRO2 can be examined by comparison with the original CMRO2 curves and the CBF curves.

Results

Fig.1 shows correlation of derived CMRO2 with the noisy CBF data and with the original CMRO2 values at CNR = 5 for CBF (typical CNR for ASL CBF about 2 to 3). The high correlation between the derived CMRO2 and the noisy CBF data strongly suggests that the derivations of CMRO2 using the model presented in [1,2] were dominated by the CBF measurements in rest-state experiments, as also shown in Fig.2. On the other hand, derived CMRO2 showed no association with the original CMRO2 data. Fig.3 shows that the derived CMRO2 values reflect true CMRO2 only when CNR for CBF measurements is greater than about 40.

Discussions

Results from our error propagation study suggest that CMRO2 estimations using CBF and BOLD are valid only when the CNR for CBF measurements is sufficiently large, or when the underlying changes in CMRO2 and CBF are sufficiently large as in hypercapnic experiments. Validity of current instantaneous CMRO2 measurements for resting-state brain functional studies is therefore in some doubt.

References

1. Hoge RD et al., PNAS 1999;96:9403-9408. 2. Wu CW et al., NeuroImage 2009;45:694-701.

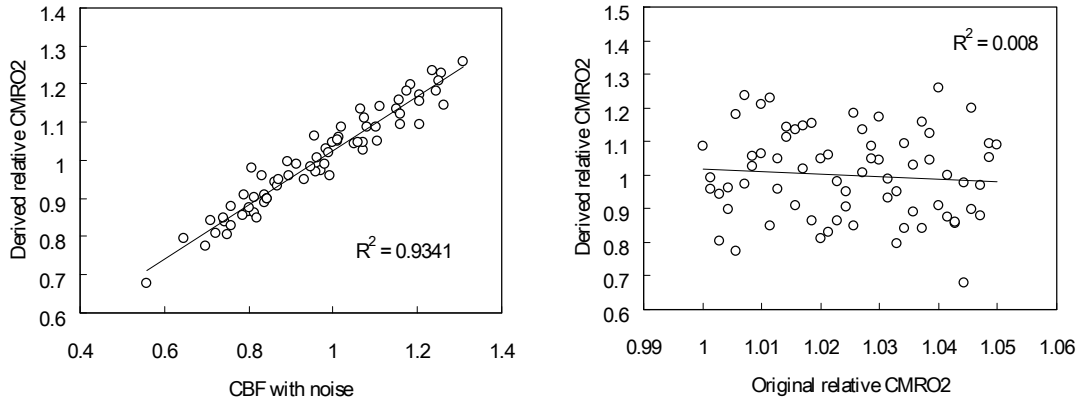

Fig.1. Strong correlation was seen for the derived CMRO2 with the CBF measurements in the presence of noise (a). On the other hand, no association was found between the derived CMRO2 and the original CMRO2 (b).

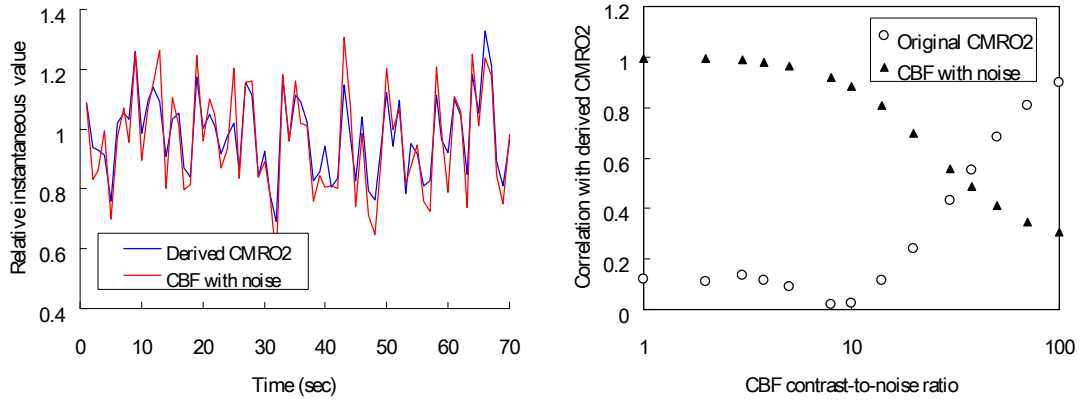

Fig.2 (left). Instantaneous relative CMRO2 values derived from the biophysical model in the presence of noise exhibit strikingly similar shapes to the CBF measurements in their signal-time curves. Fig.3 (right). Correlation coefficients with the derived CMRO2 values with the original CMRO2 (open circles) and the CBF measurements plotted as a function of CNR in CBF measurements. The derived CMRO2 values reflect true CMRO2 only when CNR is greater than about 40.