# CORRELATION STUDY OF CEREBRAL BLOOD FLOW AND EEG FEATURE BASED ON CO2 STIMULATION

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**Introduction:** Cerebral blood flow (CBF) has been a critical index for quantitative brain function evaluation, such as assessment of post-stroke rehabilitation [1]. CBF measurement using arterial spin labeling (ASL) techniques is noninvasive and quantitative [2], but suffers from high costs. Electroencephalogram (EEG) has provided an alternative for CBF measurement as a more convenient and less expensive evaluation option [3]. For stroke patients, EEG features in frequency and time domain present repeatable changes as CBF decreases from normal to lower level. However, EEG feature extraction has been difficult in CBF assessment, as CBF improvement usually happens gradually in a long time course, which doesn't introduce significant short-term EEG changes [4, 5]. In this research, a new EEG feature extraction method was proposed for quantitative evaluation of gradual CBF changes, by using different concentrations of $CO_2$ as stimulus.

**Materials and Methods:** This study was approved by ethics committee. Based on previous study [6], in this study, gradual CBF increase was simulated by triggering hypercapnic responses in 10 healthy volunteers (right-handed, 8 males and 2 females, 21-27 years). Each volunteer was asked to breathe room air and three levels of $CO_2$/air mixture with $CO_2$ concentrations being 3%, 5% and 7% with informed consent obtained. Four 8 mm axial slices were acquired using PICORE QUIPSS II on a 3T GE MRI scanner (Fig.1) [7]: flip angle = 90°, TI1 = 0.8 s, TI2 = 1.6 s, TE = 3.1 ms, TR = 2s, tag thickness = 10 cm, tag-image gap = 1 cm, FOV = 24 cm and the matrix was 64×64. A total of 210 scans (7 min) were obtained. Between the 61st and 150th scan (3 min), 3%, 5% and 7% $CO_2$ were administered via a specific breathing facial mask.

Based on previous study [8], according to International 10-20 system for EEG electrode placement, EEG was recorded from C3 and C4 close to somatosensory cortex using CompuMedics Polysomnography System (Compumedics Limited, Victoria,Australia), including 4 runs (100 trials, 6s/trail) with different concentrations of $CO_2$. In each trail, the subject started finger tapping of a specified hand at t = 2s and stopped at t = 6s. The data was digitized by a sampling frequency of 128 Hz and band pass filtered between 0.5 and 30 Hz. Totally 16 frequency points within 6-15 Hz (alpha-frequency band) and 15-24 Hz (beta-frequency band ) were chosen on the EEG power spectra. The mean and variance of these points were evaluated, yielding a 4-D feature matrix (the mean and the variance in alpha frequency band, the mean and the variance in beta frequency band). These points were classified into two groups: right hand and left hand, by using a Fisher classifier. A moving window ranged between alpha and beta frequency bands was selected. At each position of the moving window, a feature matrix was calculated and classified to obtain a correct recognition rate (CRR). The frequency step of the moving window was 1/64 Hz to yield a 576×576 accuracy matrix, demonstrated in Fig.2. The weighted average accuracy index (WAAI), as a novel index was introduced to evaluate the equivalent correct recognition rate for whole trails. The WAAI value was calculated by summing over all the CRR values multiplied by the number of the correct frequency window (NCFW).

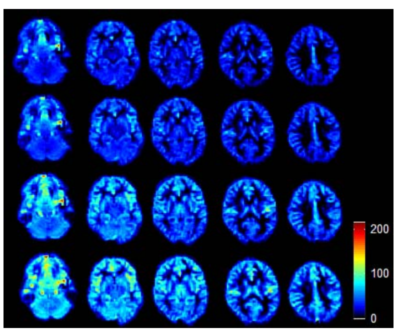


Figure 1: CBF results at different $CO_2$ concentrations from a typical subject. From top to bottom: room air, 3%, 5% and 7%. CBF increased with $CO_2$ levels.

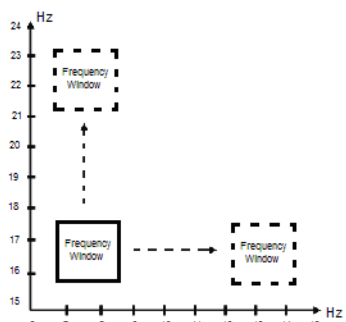


Figure 2: The moving frequency window (1 Hz × 1 Hz) stepped by 1/64 Hz. Each position corresponds to a special accuracy result.

$$WAAI = \sum (CRR \times NCFW) \quad (1)$$

**Results:** For most of the subjects, with the increase of $CO_2$ concentration, the mean CBF of selected ROI (somatosensory area) demonstrated a rising trend (Fig.1). Reasonable positive correlation between CBF and $CO_2$ concentrations was observed, shown in Fig.3 left. Moreover, as $CO_2$ concentration grew, WAAI values went up remarkably (Fig.3 middle). The corresponding values of CBF and WAAI under the four different $CO_2$ concentrations(room air, 3%, 5% and 7% ) was plotted in Fig.3 right, and a strong relationship between CBF and WAAI was indicated with a correlation coefficient of 0.70 (p=0.04).

**Conclusions:** In this study, a novel WAAI index was introduced to estimate the change of EEG pattern with the gradual CBF improvement due to the increase of $CO_2$ concentration. The group results indicated that the WAAI had a significant growth with the increase of $CO_2$ concentration. Moreover, a strong relationship between WAAI and CBF was observed in healthy subjects under $CO_2$ administration. The proposed EEG pattern related WAAI index could be helpful to evaluate the extent of brain perfusion recovery.

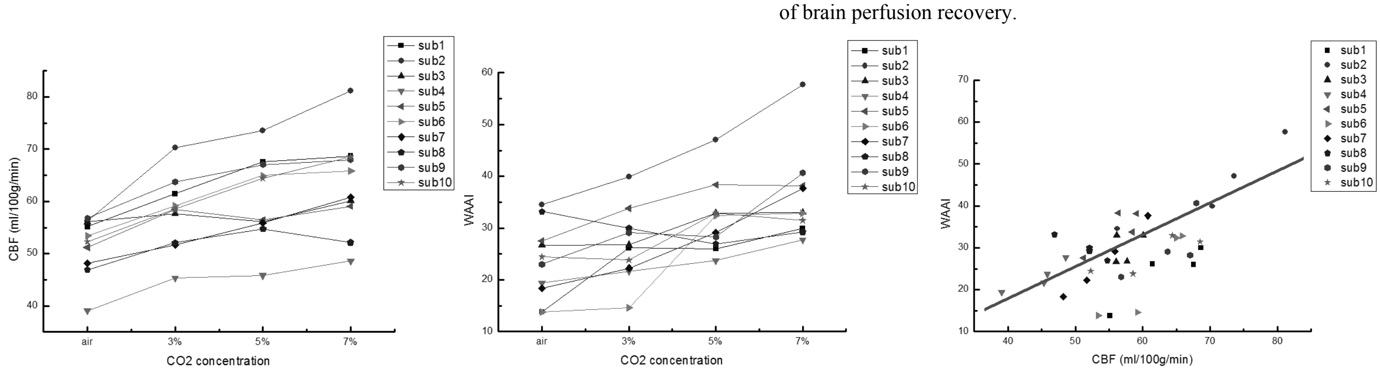


Figure 3: Data were taken from 10 healthy subjects.
From left to right: Relationship between CBF and $CO_2$ concentrations; WAAI curves; Correlation between WAAI and CBF.

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