Advanced MRI Scientific Session

SS02-1

Analysis of Fluctuation in Cerebral Venous Oxygenation Using MR Imaging: Quantitative Evaluation of Vasomotor Function of Arterioles

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Purpose

The vasodilation and vasoconstriction properties (vasomotor function) of cerebral arterioles has been studied by using vasodilators such as Diamox that are challenging to volunteers. Focusing on the natural arteriolar vasomotion induced by respiratory variation of blood CO2, we have reported a drag-administration-free method to evaluate vasomotor function in situ by spectral analysis of venous MRI signal. However, in this method, the harmonics of cardiac pulsation component are aliased and potentially contaminate the respiratory component that reflects vasomotor function. In this study, we improved our method by observing aliased cardiac frequencies and removing the contaminated data. And we applied this improved method to male young non-smokers and smokers to evaluate the influence of smoking on vasomotor function.

Materials and Methods

A single slice perpendicular to the superior sagittal sinus was imaged for 45 s by using SE-EPI (TR = 250 ms, TE = 30 ms) at 3 T for 7 non-smokers (22.6 ± 1.1 years) and 6 smokers (24.7 ± 2.2 years, smoking history 4.3 ± 2.1 years). This time series of imaging was repeated for 5 slice thicknesses (7-15 mm). Respiratory frequency during scan was fixed at 0.25 Hz by displaying a metronome to volunteers. To investigate the chronic and acute influences of smoking, smokers were imaged after abstaining from smoking for more than 8 hours (pre-smoking) and immediately after smoking (post-smoking), respectively. The time courses of MR signal of superior sagittal sinus were Fourier-transformed and the spectral fluctuation intensity (ΔS) at respiratory frequencies (0.2−0.3 Hz) was obtained. As aliasing of harmonics of the cardiac pulsation frequency component potentially contaminates the respiratory frequency component, the ΔS which suffered from this contamination were excluded from further analysis by observing the cardiac frequency. From the plot of ΔS versus average signal intensity (S) of superior sagittal sinus, the respiratory fluctuation of blood oxygenation (ΔYr), which reflects the vasomotor function, was obtained by the following equation of our method based on the relation between venous transverse relaxation rate and the venous blood oxygenation (Y).

$$\Delta S/S = 2C \cdot (1-Y) \cdot TE \cdot \Delta Yr \quad (1)$$

The ΔS/S is the slope of the regression line of the plot of ΔS versus S. To quantify ΔYr, we substituted the values of a constant C (59) and Y (0.66) in Eq. 1 from the literatures.

Results and Discussion

The ΔYr of smokers at pre-smoking (0.7 ± 0.3%) significantly decreased from that of non-smokers (1.2 ± 0.4%) as shown in Fig. 1 ($p<0.05$). This result shows the degeneration of vasomotor function due to chronic smoking even for a few years. The acute effect of smoking was also observed in smokers; ΔYr decreased from pre-smoking (0.7 ± 0.3%) to post-smoking (0.3 ± 0.2%) as shown in Fig. 1 ($p<0.01$). This result agrees with a Doppler ultrasound study by using carbogen, reflecting an acute effect of nicotine that makes arterioles vasodilate so as to diminish the vasodilation effect of CO2.

Conclusion

We improved our drag-administration-free method and demonstrated how the cerebral arteriolar vasomotor function of young volunteers is influenced by chronic and acute smoking.

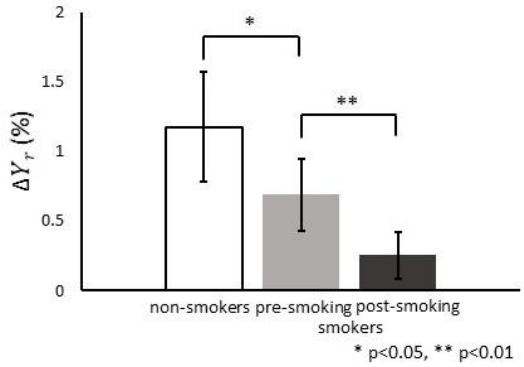

Fig.1. Respiratory fluctuation of venous blood oxygenation (ΔYr) of non-smokers and smokers. Smokers were investigated before (pre-smoking) and after smoking (post-smoking).

Keywords : Blood oxygenation, Arteriole, Vasomotion

Advanced MRI Scientific Session

SS02-2

Compartment-based Spatial Localization in Quantitative MRI and MRS

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Spectral Localization by Imaging (SLIM) based magnetic resonance (MR) methods provide a new framework that overcomes major limitations of FT-based reconstruction algorithms [1]. SLIM-based methods can be particularly appreciated where MR measurements provide the intrinsically low signal-to-noise ratio (SNR) in combination with significant physiological or biochemical differences between compartments with complex geometry. We present new emerging methods with the applications of SLIM concepts to MR spectroscopy (MRS) and cerebral blood flow (CBF) measurements.

B0-Adjusted and Sensitivity-Encoded SLIM (BASE-SLIM) is a new advanced spectral localization technique, which enables us to obtain accurate and robust MR spectra from compartments with complex shapes such as gray matter (GM) and white matter (WM) in the human brain [2]. Therefore, tissue-type specific MRS from arbitrary shaped volume of interest (VOI) can be achieved while Fourier transform (FT)-based MRS methods allow only rectangular voxel shapes that do not conform the shapes of brain structures or lesions. In spite of promises of SLIM, its applications have been limited to date due to the restrictive assumption of compartmental homogeneity, which can lead to localization errors of MRS signals. The BASE-SLIM overcomes limitations of conventional SLIM by incorporating B0 and B1 inhomogeneity information in the reconstruction model throughout VOI in a significantly reduced scan time by removing or reducing the time-taking conventional k-space encoding using gradients. Thus, clinical applications of BASE-SLIM should allow reliable assessment of tissue-type or region specific concentrations of metabolites.

Another important application of SLIM is in CBF measurements, which is commonly measured non-invasively using arterial spin labeling techniques [3]. Despite recent advancement of MR techniques in CBF measurements, the spatial resolution of CBF maps is relatively poor due to the intrinsically low SNR of perfusion signals on the order of 1–2% of general MRI signals. Most CBF techniques cannot provide sufficient spatial resolution to accurately quatify CBF in GM and WM separately because of the discrepancy between achievable vs. required spatial resolution of CBF measurements. Furthermore, significant differences of CBF between GM and WM (~3 folds) demand more stringent requirement of the spatial localization accuracy. We present a new approach to quantify CBF based on SLIM. SLIM-CBF incorporates high-resolution anatomical information into CBF reconstruction and provides accurate CBF values in compartments with complex shapes. The SLIM-CBF also allows a consistent GM and WM CBF contrast at a variety of input CBF resolutions in constrast to severe blurring in the FT reconstruction. The major advantage of SLIM-CBF is its capability to acquire accurate CBF values in GM and WM using low resolution CBF MRI, which significantly accelerate data acquisition.

In conclusion, the SLIM-based reconstruction is a promising strategy to accelerate MR data acquisition with accurate measurements of MRS and CBF signals in compartments with complex shapes, where conventional approaches fail because of the limited spatial resolution due to intrinsically low SNR of currently available MR techniques.

References

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