INVESTIGATION OF GLOBAL EFFECT OF ISCHEMIC STROKE BASED ON OXYGEN EXTRACTION FRACTION ESTIMATION

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Introduction

Ischemic stroke (IS) leads to local metabolic and functional impairment in the vicinity of the lesion [1]. However, the global effect of IS remains to be clarified. In this study we aimed to explore the global effect of IS by estimating the cerebral oxygen extraction fraction (OEF) based on the magnetic resonance susceptibility weighted imaging (SWI).

Methods

This study was approved by local institutional review board. Informed consent was obtained for each of the fifteen subjects consecutively recruited with first ever single IS lesion identified (f/m=6/9, average age 60.8±12.5 years). SWI was performed at 4.4±2.9 days post stroke on a 1.5T scanner (Siemens, Erlangen, Germany) with a standard 12 channel head coil with parameters TR/TE 49/40ms, flip angle 15°; field of view 186×230 mm^2, in plane resolution 0.36×0.36×1.60 mm^3, slice thickness 3mm, bandwidth 80 Hz/ pixel, 60 slices. The SWI phase data was high-pass filtered by a central matrix size of 32×32 using SPIN (signal processing in NMR) software (Detroit, Michigan).The phase difference between the blood vessel and the surrounding tissue can be expressed as: $\Delta\varphi = 2\pi \cdot \gamma \cdot B_0 \cdot \Delta\chi \cdot \left(\cos^2\theta - \frac{1}{3}\right) \cdot TE$, where γ is the gyro-magnetic ratio of the proton(2.67×10^8rad/s/T), θ is the angle between the blood vessel and the static magnetic field B_0. The average phase change across the vessel is measured by $\Delta\varphi = \left((\Delta\varphi_1 - \Delta\varphi_2) + (\Delta\varphi_3 - \Delta\varphi_2)\right)/2$, $\Delta\varphi_1, \Delta\varphi_2$ are the phase difference located at the two interfaces of vessel-tissue cross section, respectively (Figure 2). $\Delta\varphi_3$ is the phase difference at the lowest point of the vessel phase profile. And $\Delta\chi$ is expressed as $\Delta\chi = \Delta\chi_{do} \cdot Hct \cdot OEF$ (Eq.3), where $\Delta\chi_{do}$ is the change in blood susceptibility per unit hematocrit between fully deoxygenated and fully oxygenated blood(1.8×10^{-7}). Hct is the percent of red blood cells in a given volume(usually selected as 40).OEF was estimated in selected vessels of the representative brain areas in the vicinity of (OEF-lesion) and remote to the IS lesion (OEF-R) for both hemispheres based method in reference 2 (Figure 1). OEF in the sagittal sinus (OEF-S) was taken as a convenient reference representing the whole-brain average[3]. P<0.05 was set as the significance level for statistic analysis.

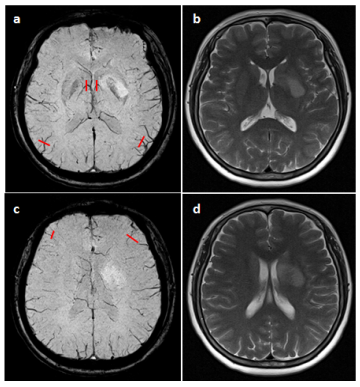

Figure 1. Vessel selection in the minimum intensity projection image of SWI (a,c) referring T2WI to locate the IS lesion.

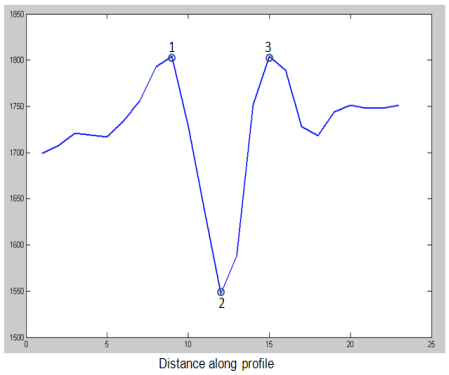

Figure 2. Phase profile of the susceptibility changes between the tissue and vessel of a subject.

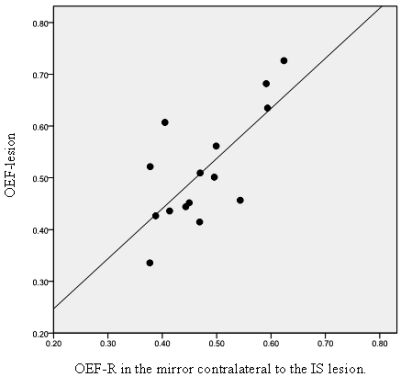

Figure 3. OEF-R was significantly correlated with OEF-lesion (R^2=0.42, F=9.34, r=0.65, P<0.005).

Results

OEF-R in the ipsilateral (0.37±0.07) and contralateral (0.39±0.05) hemispheres were significantly lower than OEF-lesion (0.52±0.12) (P<0.001) and OEF-S (0.59±0.10) (P<0.0001). OEF-lesion and OEF-S were comparable (P=0.15). OEF-R in the contralateral mirror area of the IS lesion was significantly higher than OEF-R in other areas (P<0.02), and robustly correlated with OEF-lesion (R^2=0.42, F=9.34, r=0.65, P<0.005, Figure 3). As OEF is fairly stable across cortices [4] under healthy condition, the increased OEF-S may imply a global cerebrovascular response to the focal IS event.

Discussion

As increased OEF in the vicinity of IS lesion was reported to be associated with a preserved autoregulatory capacity in the scenario of ischemic attack and may function as an indicator to predict the risk for future stroke [1], the elevated OEF-R in this study may suggest an extensive compensation mechanism of metabolic modulation in oxygen consumption and cerebral perfusion to maximize the functional rebalance at the global level. However, the clinical relevance needs to be further investigated.

Conclusions

Focal ischemic lesion triggers global compensative effect in human brain as indicated by the variation of the oxygen extraction fraction. This preliminary study may provide a meaningful reference for future researches towards a better understanding of the disease dynamic of IS.

References:

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3. Jain V, et al. J Cereb Blood Flow Metab 2010; 30:1598-1607. 4. Kety SS and Schmidt CF. J Clin Invest 1948; 27:476-483.