The impact of fluctuated tCBF induced by cardiac pulsation on the global CMRO2 measurement

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Purpose

The global cerebral metabolic rate of oxygen ($CMRO_2$) is an important indicator to the whole brain because the primary metabolic fuel of energy production in the normal brain is aerobic metabolism of glucose. Recently, the global $CMRO_2$ is quantified with the total cerebral blood flow (tCBF) and venous oxygen saturation (SvO_2) levels measured with the MRI approaches noninvasively[1]. In this research, the impact of fluctuated tCBF induced by cardiac pulsation on the global $CMRO_2$ measurement and the correlation of tCBF with SvO_2 are demonstrated in healthy subjects.

Materials and Methods

The MRI experiments were executed using a 3T MR system (GE Discovery MR750 with an 8-channel head coil) and data from ten subjects (six male and age = 24±3) were included. The phase contrast magnetic resonance angiography of 2D cardiac gating gradient echo imaging was conducted to quantify tCBF with the following parameters: TR/ TE = 8.3/4.7msec, matrix size = 256×256×1, voxel size = 0.9×0.9×3mm^3, repetition number per cardiac cycle =30 and velocity encoding = 60cm/sec. The 3D multiple gradient echo imaging (6 echoes) was conducted to quantify SvO_2 of superior sagittal sinus (SSS) with the following parameters : TR = 31.4msec, TE = 5.4 ~ 27.5msec, matrix size = 512×512×84, voxel size = 0.45×0.45×3mm^3, flip angle = 15° and bandwidth = 244Hz/pixel. The T1-weighted images were acquired to localize one slice containing the region of interest (ROI) in SSS parallel to the main magnetic field and brain weight of 1500g is assumed in CBF quantification.

The velocities of bilateral internal carotid arteries (ICA) and vertebral arteries (VA) were derived from four ROIs (**Figure 1a**) of phase and magnitude images (**Figure 1 b**) in the axial slice vertical to these four arteries. The CBF of each artery was quantified with its velocities and summed to measure the tCBF at each time point during one cardiac cycle. The phase difference between SSS and bilateral neighboring parenchyma ROIs (**Figure 1c**) was measured in the high pass filtered (128×128) phase image[2] of first echo in muti-echo images to quantify SvO_2. The tCBF and SvO_2 were applied to quantify the $CMRO_2$ with the Frick's equation: $CMRO_2 = Ca \times CBF \times (SaO_2 - SvO_2)$ with the oxygen concentration in moles of O_2 per 100mL of blood (Ca) = 836 μmol/100mL. Other constant assumptions for quantification were the same as in the reference 1. The mean and standard deviation of tCBF were obtained during one cardiac cycle to derive mean and standard deviation of $CMRO_2$.

Results

The SvO_2 and mean and standard deviation of tCBF and $CMRO_2$ for ten subjects were listed (**Table 1**). The coefficient of variation for most subjects induced by cardiac pulsation was from 16% to 25% both for tCBF and $CMRO_2$, except the coefficient of variation = 8% for 9th subject. The SvO_2 and mean or maximum values of tCBF were scatter plotted to probe their relationship (**Figure 2**). It showed SvO_2 was correlated both with mean and maximum tCBF and their linear regression functions were tCBF= 155×SvO_2-87.9 with r^2=0.18 and tCBF= 149.9×SvO_2-66.9 with r^2=0.16, respectively.

Conclusion

The 18% group variance of tCBF induced by cardiac pulsation should be considered in the global $CMRO_2$ measurement although the correlation between tCBF and SvO_2 was remained during cardiac cycle.

Discussion

Although the ROIs were obviously appeared in the phase and magnitude images, the effect of ROI selection to $CMRO_2$ quantification should be further investigated. Because the SvO_2 derived from filtered phase was higher than previous literatures[1], different strategies should be applied in instead of high pass filter for phase unwrapping and the removal of field inhomogeneities, such as projection dipole fields for the removal of field inhomogeneities[3].

References

1. Jain et al., J Cereb Blood Flow Metab, 2010;30:1598-1607; 2. Fujima, Neuroimage, 2011;54:344-349; 3. Liu, NMR in Biomed, 2010;24:1129-1136

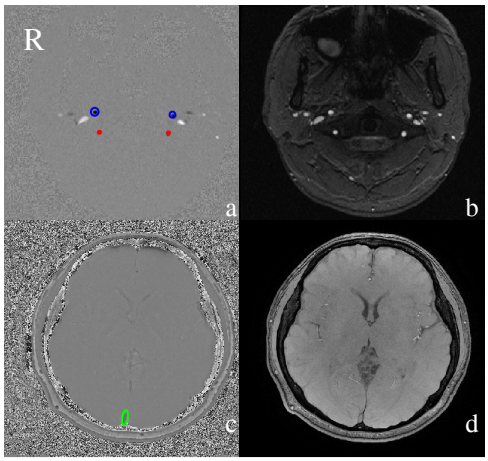

Figure 1 The phase (a)(c) and magnitude images (b)(d) were shown in neck (a)(b) and SSS (c)(d) level. The ICA, VA and SSS ROIs were indicated in blue, red and green. B0 is the magnetic field.

	SvO_2	tCBF	$CMRO_2$
1	91.0	61.8±13.1	36.2±7.6
2	92.4	48.5±8.6	22.6±4.0
3	90.5	46.2±11.4	28.9±7.1
4	89.0	43.0±7.2	32.4±5.4
5	86.8	48.3±9	45.1±8.4
6	90.6	37.0±7.8	23.0±4.9
7	85.7	54.2±8.8	55.7±9.0
8	89.0	57.0±10.5	42.8±7.9
9	93.3	70.4±5.7	28.4±2.3
10	84.6	39.7±7.3	44.4±8.2

Table 1 SvO_2(%), tCBF(mL/100g/min) and $CMRO_2$(μmol/100g/min)of ten subjects (1-10) were summarized by mean and one standard deviation.

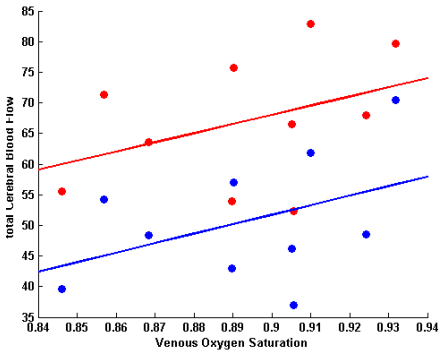

Figure 2 The scatter plot of SvO_2 (x axis) and mean (blue) or maximum (red) tCBF (y axis) was derived in ten patients (1-9). The r^2 of linear regression for mean and maximum tCBF was 0.18 and 0.16, respectively.