Improving the Sensitivity of Total Cerebral Blood Flow Measurement by Cine Phase Contrast MRI

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Introduction

Cerebral Blood flow (CBF) is being measured by different modalities including Xenon enhanced CT, dynamic susceptibility contrast MRI, and positron emission tomography. These modalities measure regional CBF for a given brain's weight. Cine phase contrast (PC) MRI techniques have been used to measure total CBF (tCBF) by summation of mean volumetric flow rate (VFR) through arteries supplying blood to the brain [1]. However, these measurements have shown large inter-individual variability. This study aims to determine whether whether tCBF, normalized for brain volume, has a smaller inter-individual variability.

Methods

Velocity encoded (VENC) cine phase contrast scans were obtained in 7 healthy subjects (3M:4F; 21±2 years) with a 3T scanner (GE healthcare) using 6mm slice thickness, 14cm field-of-view, 25 degrees flip angle, 18ms repetition time, 6.2 echo time, VENC of 70cm/s, and 256*128 matrix. Slices were placed transverse to the axis of the internal carotid and vertebral arteries. Volumetric flow rates were obtained by integration of velocities inside the lumen's cross-sectional area. Vessel lumen boundary was determined automatically using the pulsatility based segmentation (PUBS) method [2]. The PUBS method was shown to increase measurement's accuracy and reproducibility [2]. Possible baseline shift caused by imperfect suppression of eddy currents was corrected by subtraction of the mean velocity in a background region of interest. Mean volumetric flow through the internal carotid and vertebral arteries were summed to obtain tCBF in units of volumetric flow rate (mL/min).

Volumes of brain gray (GM) and white matter (WM) were quantified from 3D axial T1 weighted SPGR images acquired with 1.5mm slice thickness, 24cm field-of-view, 9ms repetition time, and 1.8 echo time. Segmentation of GM, WM, and CSF regions was obtained using the FAST brain segmentation tool (FMRIB, Oxford, UK) [2]. Normalized tCBF (N-tCBF) were then obtained for each subject by dividing tCBF with the subject's GM and WM volumes weighted by their relative CBF (Xenon CT study has shown a 2.5:1 ratio of GB:WM CBF [3]) and multiplying by brain density. Average, SD, and percentage SD of tCBF (in mL/min) and N-tCBF (in mL/min/100g) were derived and compare. Finally, the relationship between tCBF and brain volume was determined

Results

Figure 1a and 1b show a velocity encoded image and a segmented brain image from one of the subjects used for the derivation of tCBF and N-tCBF, respectively. Mean, SD, and %SD of GM, WM, tCBF, and N-tCBF are listed in Table 1. The relative tCBF and N-tCBF inter-individual variability were 16.5 and 9.5%, respectively. Normalization of tCBF for brain volume has reduced the inter-individual variability by over 40%. A statistically significant linear correlation (R= 0.87) was found between the weighted GM and WM volumes and tCBF.

Conclusions

The current sensitivity of total CBF measurement by phase-contrast MRI is limited by large inter-individual variability (e.g., 20% in [1]). Significantly improved sensitivity (below 10% inter-individual variability) can be achieved by automated lumen boundary identification and by normalization for brain volume.

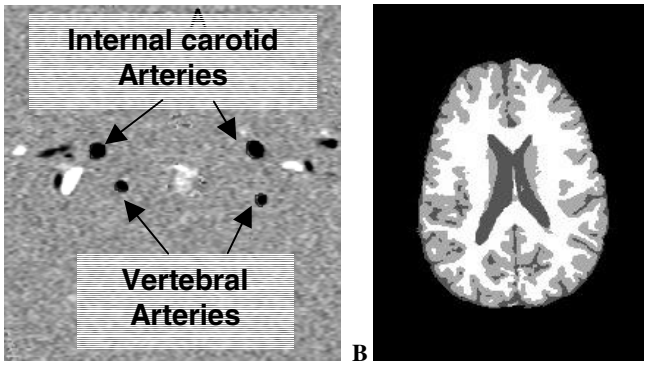

Figure 1. A: Velocity encoded image of blood flow through arteries leading blood to the brain. B: Segmented brain MR image into CSF (dark), GM (light grey), and WM (white) regions.

	GM cm^3	**WM** cm^3	**tCBF** mL/min	**N-tCBF** mL/min/100g
Mean	696	486	830	88.4
SD	66.1	43.7	137	8.4
%SD	9.5 %	9.0 %	16.5 %	9.5 %
Literature ref.				
[1]	PC-MRI: Mean tCBF 858±176 (%SD=20.5%)			
[3]	XeCT: Mean rCBF (GM=71, WM=28)			

Table 1. Inter-individual average, SD, and percentage SD.

References

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[3] Wintermark M et al, AJNR 2001;22:905-914.