Cerebral blood flow: comparison between ultrasound and phase contrast MRI

M. Ayaz Khan[1,2], Jie Liu[1,2], Peiying Liu[3], David Zhu[4], Hanzhang Lu[3], and Rong Zhang[1,2]

[1]*Cardiology, University of Texas Southwestern Medical Center, Dallas, TX, United States,* [2]*Institute for Exercise and Environmental Medicine, Dallas, TX, United States,* [3]*Advance Imaging Research Center, University of Texas Southwestern Medical Center, Dallas, TX, United States,* [4]*Cognitive Imaging Research Center, Michigan State University, East Lancing, MI, United States*

Introduction: Quantitative total brain blood flow (TBF) measurement is essential for assessment of cerebrovascular function under normal and diseased conditions. Color-coded duplex ultrasonography (CDUS) and phase contrast (PC) magnetic resonance imaging (MRI) are two commonly used non-invasive techniques for measuring TBF. However, previous studies showed substantial differences between these two methods(1-2). Recent development in ultrasoud technology and quantification of blood vessel diameter using the edge-detection and wall-tracking method have significantly improved the accuracty of TBF measurement using CDUS(3). In the present study, we compared TBF meauserments using the PC MRI with the high-resolution 2-D CDUS methods.

Methods: *MR DATA collection:* Thirty eight normal controls participated (mean age 48±15). MRI data was collected on a 3T Achieva system (Philips Medical Systems), using an 8 channel transmit/receive head coil. Velocity images were placed perpendicular to the vessels of interest above the bifurcation of internal carotid arteries based on the TOF MR angiographic image. Non-cardiac gated PC MRI images were collected using the following parameters: voxel size = 0.45 x 0.45 x 5 mm^3, FOV =230 x 230 x 5 mm^3, maximum velocity encoding = 80 cm/s and NEX 4.

Ultrasound data collection: A 3-12 MHz linear array transducer on the CDUS system (CX-50, Phillips Healthcare) was used for TBF measurements. The measurements for the ICA were performed at least 1 cm above the carotid bifurcation and for vertebral artery (VA) between the C_4 and C_6 intertransverse segments. Subjects were in a supine resting position for more than 10 minutes before data collection to stabilize hemodynamics. Subjects were asked to refrain from high intensity exercise, alcohol, or caffeinated beverage at least 24 hours before tests.

Data Analysis: PC data were analyzed using MATLAB (Mathworks, Natick, MA, USA). Regions of interest (ROIs) were manually drawn on each of the arteries using magnitude images. Vessel masks were generated and then applied to the phase images to obtain blood flow and velocity. Velocity was calculated by averaging values within the ROI. Flow was calculated by multiplying the velocity and area of the vessel. For CDUS data analysis, a straight vessel segment with a parallel wall view was identified where the luminal diameter remained the same for a length of at least 0.5 cm to enhance the uniformity of Doppler sample volume. The sample volume was positioned at this site to cover the entire vessel lumen to measure angle-corrected mean velocity. At least 5 complete cardiac cycles of consecutive blood flow velocity waveforms were recorded to obtain the time-averaged mean velocity (TAMV). For vessel diameter measurement, the distance between the parallel internal layers at the sample volume site was measured using an edge-detection and wall-tracking technology (resolution, ~ 0.01mm) to obtain time averaged vessel diameter from 3 consecutive cardiac cycles (Brachial and Carotid Analyzer, Medical Imaging Applications). Volumetric TBF was calculated by multiplying the mean velocity and area of the each vessel. Flow and velocity data were presented as mean ± SD (Table 1). Correlations between the two techniques were performed using the Pearson product-moment correlation coefficient (R). A P value < 0.01 was considered statistically significant.

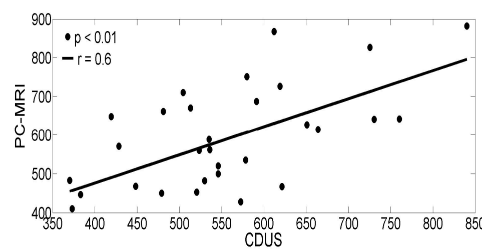

Figure1: Correlation between flow measurements

Results: Significant correlations were observed in TBF measurements between CDUS and PC for all four arteries of interest: Left ICA (R=0.6), right ICA (R=0.6), left VA (R=0.9) and right VA (R=0.8) (all p<0.01). Total TBF calculated as a sum of all four arteries, showed a significant correlation between the two techniques (R = 0.6, p<0.01) (Figure 1). Group averaged TBF is listed in Table 1. No significant differences between PC MRI and CDUS were observed although ICA TBF measurements using PC were slightly higher as compared to CDUS.

	Doppler-US	PC-MRI
Left-ICA	201 ± 58	227 ± 57
Right-ICA	202 ± 53	216 ± 65
Left-VA	87 ± 42	83 ± 36
Right-VA	64 ± 33	61 ± 37
Total	553 ± 110	588 ± 137

Table 1: Flow measured in ml/min

Discussion: CDUS and PC MRI are non-invasive techniques for TBF measurements in clinical settings. This study shows significant correlations between these two methods for TBF measurements in all four major cerebral arteries. The larger differences in the ICA TBF measurements between the two methods may reflect intrinsic larger diameter and velocity variability in the ICA relative to the VA.

References: 1). Ho SS et al AJR Am J Roentgenol. 2002 Mar;178(3):551-6, 2). Oktar SO et al. AJNR Am J Neuroradiol. 2006 Feb;27(2):363-9. 3) C. K.Willie1, J Physiol 590.14 (2012) pp 3261–3275