Blood Volume Flow Rates of Vessels in Healthy Human Cerebral Vasculature

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Target Audience: Clinicians and scientists interested in blood flow through the cerebral vessels.

Purpose: To establish volume flow rates (VFR) [1] in cerebral vessel segments for a population of normal healthy subjects. By establishing VFR measurements for cerebrovascular segments in a healthy population, these measurements could be used to compare and determine abnormal flow in disease states such as arteriovenous malformation and cerebral aneurysm.

Methods: Twelve healthy normal subjects were imaged. Imaging was performed on a 3-T MR scanner (Discovery 750, GE Healthcare, Waukesha, WI, USA). Phase contrast MR imaging measurements of flow velocity were used to calculate the VFR. The imaging sequence had a TR/TE/α = 8.2 ms/3.8 ms/10°, acquired matrix of 192 × 256 × 196; a field of view of 16.5 cm × 22 cm × 19.6 cm and a venc = 150 cm/s. Cut planes were placed through twenty-six vessel segments in each subject (vessel segments are listed on the horizontal axis of the figure below), and the surface integral of the flow velocity was calculated to yield the VFR. The mean and standard deviation across the population of the flow through each vessel segment was then calculated.

Results: The figure below shows the measurements grouped by vessel segment. The gray bars represent the flow measured in the individual subjects and the black bar represents the mean and standard deviation across the group for the respective vessel segment. Although flow on the left side was generally higher, no statistical significance was found between paired left and right carotid vessel segments.

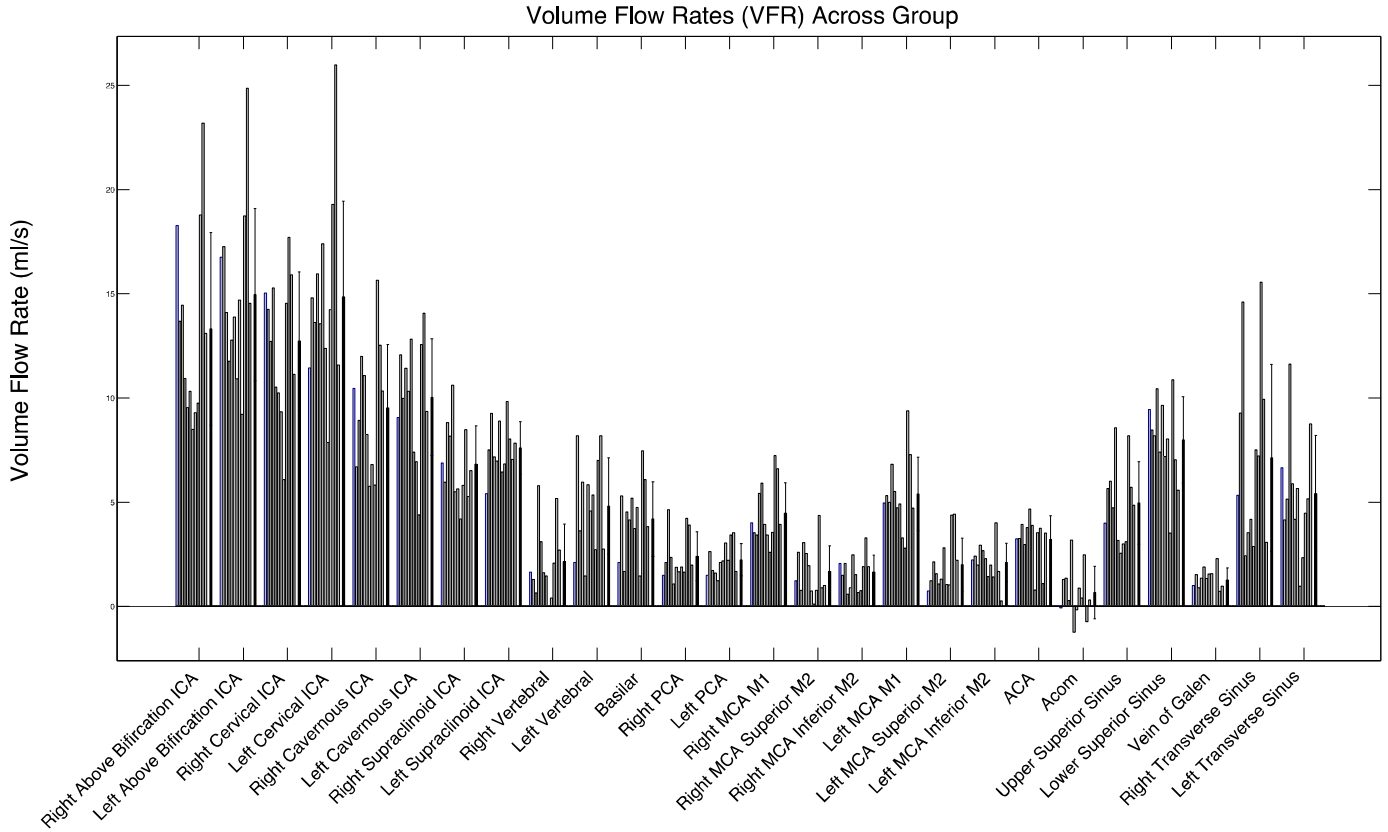

Figure 1: Volume flow rate measurements from a healthy population. The gray bars indicate the measurements from the individual subjects and the black bars with the error bars represent the mean and standard deviation for the respective vessel segment.

Discussion: Flow is known to have a high degree of biological variability, even among healthy individuals. This variability is observed in our data as well. The standard deviation is on the order of 20-30% of the mean flow. In the case of the Anterior Communicating Artery (ACA), where flow can be bi-directional, the standard deviation of the VFR is actually higher than the mean flow. Carotid artery flow volumes rates have been more thoroughly studied [2,3], and the numbers presented here closely match measurements in these previous studies.

Conclusion: In this work, blood flow is parameterized in terms of the VFR for vessel segments of the cerebrovascular system with diameters of greater than 1 mm. The ratio of the standard deviation to the mean indicates the biological variability of this cohort.

References: [1] Joseph AA, Merboldt KD, Voit D, Zhang S, Uecker M, Lotz J, Frahm J. Real-time phase-contrast MRI of cardiovascular blood flow using undersampled radial fast low-angle shot and nonlinear inverse reconstruction. NMR in Biomedicine. 2012;25(7):917-924 **[2]** Kadbi M, Negahdar M, Traughber M, Martin P, Amini AA. Assessment of flow and hemodynamics in the carotid artery using a reduced TE 4D flow spiral phase-contrast MRI. 35th EMBC Annual International Conference of the IEEE. 2013: 1100-1103 **[3]** Harloff A, Zech T, Wegent F, Strecker C, Weiller C, Markl M. Comparison of Blood Flow Velocity Quantification by 4D Flow MR Imaging with Ultrasound at the Carotid Bifurcation. American Journal of Neuroradiology. 2013(In Press)