Cerebral arterial and venous flow measurements in the neck for patients with multiple sclerosis

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Introduction: Recently, there has been an increased interest in the role of poor venous flow in patients with multiple sclerosis (MS) (1). The goal of this work is to understand the flow characteristics of both the major arteries and veins in the neck in an MS population. By using phase contrast MR imaging, we can evaluate the flow in a variety of locations to examine the total cardiovascular input/output to and from the brain. In this preliminary study, we will examine a total of 127 MS cases and present a variety of quantitative measures of the arterial and venous flow.

Methods: Institutional review board approval was obtained for the human imaging protocols performed. A total of 127 MS patients were scanned with a variety of conditions. These include relapsing remitting, secondary progressive, primary progressive, and progressive relapsing. Blood flow is measured with two dimensional PCMRI imaging on a 3T Siemens Magnetom Tim Trio with the following parameters: repetition time = 14.4ms, echo time = 4.41ms, flip angle = 25^{o}, field of view = 256mmx256mm, acquisition matrix size = 448x448, in-plane resolution = 0.57mmx0.57mm, slice thickness = 4mm and velocity encoding (VENC) = 50cm/sec. Pulse gating was used to monitor and trigger the data acquisition. Images were acquired for a total of 25 time points during the cardiac cycle. The imaging plane was chosen to be at the cervical 6/7 level at the lower neck and perpendicular to the internal jugular veins (IJV). Our in-house software (written in MATLAB) was used to segment vessels and compute flow. Vessel segmentation was achieved manually. In some cases the blood flow velocity exceeded our VENC and resulted in phase aliasing. This was corrected by running a simple phase unwrapping algorithm that takes into account the

phase values of all the voxels throughout the cardiac cycle inside the vessel. Blood flow velocities through both veins and arteries were measured throughout the cardiac cycle. The volume flow rates at individual time points were computed by multiplying the spatial average velocity with the vessel lumen area. Then average volume flow rate was computed for the whole the cardiac cycle. The distribution of both arterial and venous blood flow in different vessels was computed after the flow was quantified. The mismatch between arterial flow and venous flow was computed via: VA mismatch (%) = (arterial flow – venous flow)/arterial flow * 100. The ratio of blood flow between the dominant vein that carries most of the venous blood and the 2nd dominant vein was calculated for each patient. Reflux blood flow for internal jugular veins was calculated by: reverse flow/forward flow * 100. Finally, the pulsatility index (PI) for both internal jugular veins was computed by: (Vmax-Vmin) / Vmean, where Vmax, Vmin and Vmean are the maximum, minimum and mean of the spatial average velocities for all the time points over the cardiac cycle.

Results: The main venous and arterial flows are summarized in Table 1.

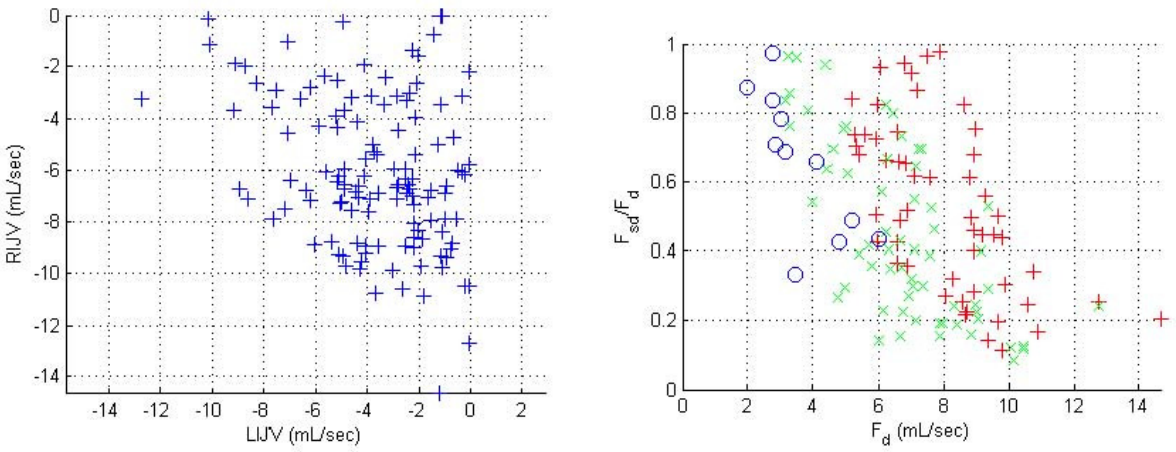

Figure 1: Left: Scatter plots of volume flow rates for left and right IJV; Right: Scatter plots of sub-dominant means total (tIJV: total IJV, tLA: total left arteries, etc.) / dominant venous flow ratio vs. dominant venous flow: +: type I; x: type II; o: type III (see [2]).

No. of patients		127	
		Mean	Std
Age (years)		47.2	10.2
HR (/sec)		71.4	10.9
Flow Rate (mL/sec)	LCCA	6.37	1.32
	RCCA	6.32	1.59
	LVA	1.72	0.72
	RVA	1.51	0.65
	LIJVRIJV	-3.74	2.52
	tIJVtA tV	-6.12	2.88
		-9.86	3.20
		16.02	2.75
		- 13.73	2.75
VA mismatch (%)		13.97	11.10
Fsd/Fd		0.50	0.25

Table 1. Flow measurements for 127 MS patients. “t”

On average, the left and right common carotid arteries carry almost the same amount of blood (6.37±1.32 mL/sec for LCCA vs. 6.32±1.59 mL/sec for RCCA). The same is true for the vertebral arteries (1.72±0.72 mL/sec vs. 1.51±0.65 mL/sec). However, the distribution of blood flow through the VAs is much more spread out than the CCAs. The blood flow through the RIJV (-6.12±2.88 mL/sec) is significantly more than the LIJV (-3.74±2.52 mL/sec). This is consistent with the findings of others. The spread between the left and right IJVs is also much more pronounced than that of the CCAs (see Fig. 1 left). Similar findings are shown for the total left and right arterial and venous flow rates. In general, arteries on both sides carry almost the same amount of blood while the right side veins carry more blood than the left side veins. Vessel cross-sectional area is found to have more variability than the vessel flow rate, especially for the IJVs (58.4±38.2 mm^2 for LIJV and 78.4±45.6 mm^2 for RIJV). The average percentage of IJV blood flow out of the total venous flow is measured to be 71.9±19.2%. Using the categorization method in [2], out of the 127 MS patients, 42.5%

were type I, 48.8% were type II and 8.7% were type III. This is significantly different from the categorization in [2] for normals. The venous-arterial mismatch is measured to be 14.0 ±11.1%. The ratio of sub-dominant vs. dominant venous flow is 0.50±0.25. Figure 1 (right) shows the plot of subdominant flow/dominant flow ratio vs. dominant flow rate. Reflux flow was found to be 4.9±14.8% for LIJV and 1.5±6.0% for RIJV (cases with zero reflux flow were not included when calculating these measures). Finally, the pulsatility indices of the IJVs are 2.1±1.1 for LIJV and 1.9±1.0 for RIJV (cases with pulsatility index higher than 10 were not included when calculating these measures).

Discussion and Conclusions: The pronounced spread of blood flow through the left and right vertebral arteries and the left and right internal jugular veins is worth noting. It means that the blood distribution between the left and right sides can be significantly disproportionate for some patients. This could be due to various anatomical or physiological conditions. An example could be vessel stenosis on one side. Compared to the findings in [2], our measurements show that in more MS patients (48.8% for type II compared to only 22% in [2]) the internal jugular veins carry less blood out of the brain. This could be caused by CCSVI and other veins or collaterals serve as alternative pathways. It is also interesting that about 1/4 of all the MS patients have a significantly dominant vein (meaning that the 2nd dominant vein only carries less than 20% of the blood through the dominant vein).

References:

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J Neurol Neurosurg Psychiatry. 2009;80:392-399. [2] Doepp F et al. “How does the blood leave the brain? A systematic ultrasound analysis of cerebral venous drainage patterns,” *Neuroradiology*, 46: 565-570; 2004.