Left Atrial Flow Quantitification in Atrial Fibrillation

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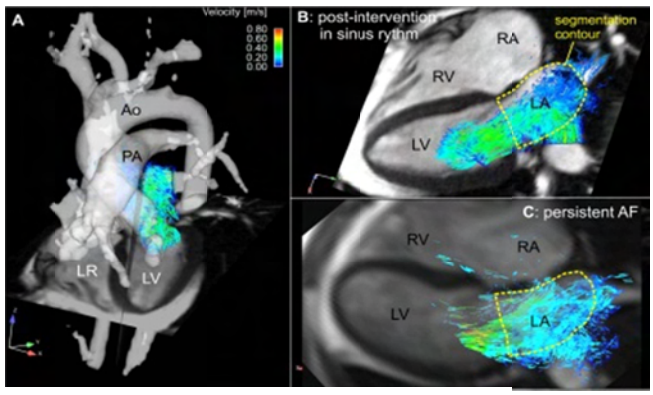
Introduction: Atrial fibrillation (AF) is a common arrhythmia characterized by irregular electrical activity in the left atrium. Thromboembolism is the most serious complication of AF, usually manifesting as stroke or systemic embolism (1). This is thought to be linked to the increased risk of thrombus formation in the left atrium due to a decrease in blood velocity or flow abnormalities. However, current tools for thrombus risk stratification in AF are coarse and a better appreciation of the underlying mechanisms and risk factors for atrial thrombus formation in the individual patient are needed to improve risk stratification and therapy planning. Phase contrast MRI is a tool that can be used to measure blood velocity *in vivo* (2). Using the recently developed 4D-flow method (3), time resolved blood velocity measurements can be made in a 3D volume with velocity encoding along each of three orthogonal directions. By comparing the velocity of flow in AF patients and healthy volunteers, it may be possible to identify blood flow patterns that lead to an increased risk of thrombus formation, and thus stroke. This information could be valuable in determining anticoagulation treatment regimens for patients with AF. This work describes initial results in characterizing blood velocity patterns within the left atria of 9 AF patients and comparing those results to similar measurements from 10 healthy volunteers.



4D flow AF (C).

Methods: MRI data were acquired from nine patients (2 women, mean age 61+/-9.7) each with diagnosed AF. Three of the patients had previously suffered strokes and three of the patients were not in sinus rhythm at the time of imaging. Data were also acquired from 10 healthy volunteers in two age groups (2 women, 5 younger than 30 years, 5 over 50 years). Informed consent was obtained from each patient and volunteer and all studies were approved by our institutional review board. Each subject underwent standard cardiac protocols on 1.5T MR systems (Siemens, Erlangen, Germany). In addition, ECG and navigator gated free breathing 4D-Flow MRI was performed for each subject (velocity sensitivity - 100-150 cm/s, spatial resolution = 2.5-3.0 mm in plane, 3.0-3.5 mm slice, temporal resolution =37.6-41.6 ms). After noise filtering, Maxwell, and eddy current correction, the 4D flow data was co-registered with a standard 2D CINE SSFP 4-chamber was co-registered (EnSight, CEI, USA) to improve anatomic orientation and to define a single slice through the left atrium as a basis for analysis of atrial velocities. The left atrium was manually segmented from this slice using the high resolution CINE image as reference (see figure 1). To test the hypothesis that subjects with AF have lower flow than healthy subjects, the top 25% of velocity magnitudes were collected from each voxel. These magnitudes were then combined into histograms and the mean and median values were compared. Vector maps displaying the in-plane velocity following the opening of the mitral valve were also generated to show the distribution of the velocity values within the left atrium.

	Mean Vel.	Median Vel.	% above 0.5 m/s
Young Volunteers	.23+/-.02	.19+/-.03	7.16+/-2.72
Older Volunteers	.16+/-.02	.14+/-.04	.87+/-1.09
Patients in Sinus	.15+/-.03	.14+/-.03	.44+/-.69
Patients in AF	.14+/-.02	.13+/-.02	.24+/-.24

Table 1 – Summary of velocities measured in patients and volunteers. All velocities represent mean +/- standard deviation in units of m/s.

Results and Discussion: The results from all the subjects are summarized in Table 1. Overall, AF patients had 35-40% lower velocity than young volunteers. They also had an average of less than 0.5% of voxels with flow over 0.5 m/s, as compared to over 7% in young volunteers. Older volunteers also had significantly lower flow than young volunteers. Figure 1 shows co-registered 4-chamber CINE images and 3D flow visualization in the atrium and ventricle during mitral in-flow. Compared to a patient after successful intervention for AF (B, in sinus rhythm), atrial flow in a patient with persistent AF (C, arrhythmic heart rate) appears more disorganized indicating the potential of the method to identify complex individual atrial flow characteristics. Figure 2 displays histograms from two AF patients (ages 60 and 71) as well as a single younger volunteer (age 29) and older volunteer (age 53). The histograms taken from the AF patients have lower mean velocities than those of the healthy volunteers. The average blood velocity in the left atrium decreases with age as measured in our volunteers. The distribution of velocities is also different between patients with AF and healthy volunteers. The second row of Figure 2 displays the magnitude of the in-plane velocities for each of the subjects immediately following the opening of the mitral valve. In each case, the image is oriented such that the mitral valve opening is at the bottom of the image. As seen in the histograms, the AF patients have generally lower velocities than the healthy volunteers, and the younger volunteers have higher overall velocities. A qualitative analysis of the velocities suggests that AF patients have low left atrial blood velocities. Future work will focus on expanding our analysis to three dimensions and developing quantitative measures to classify blood flow patterns and describe the risk of thrombus formation.

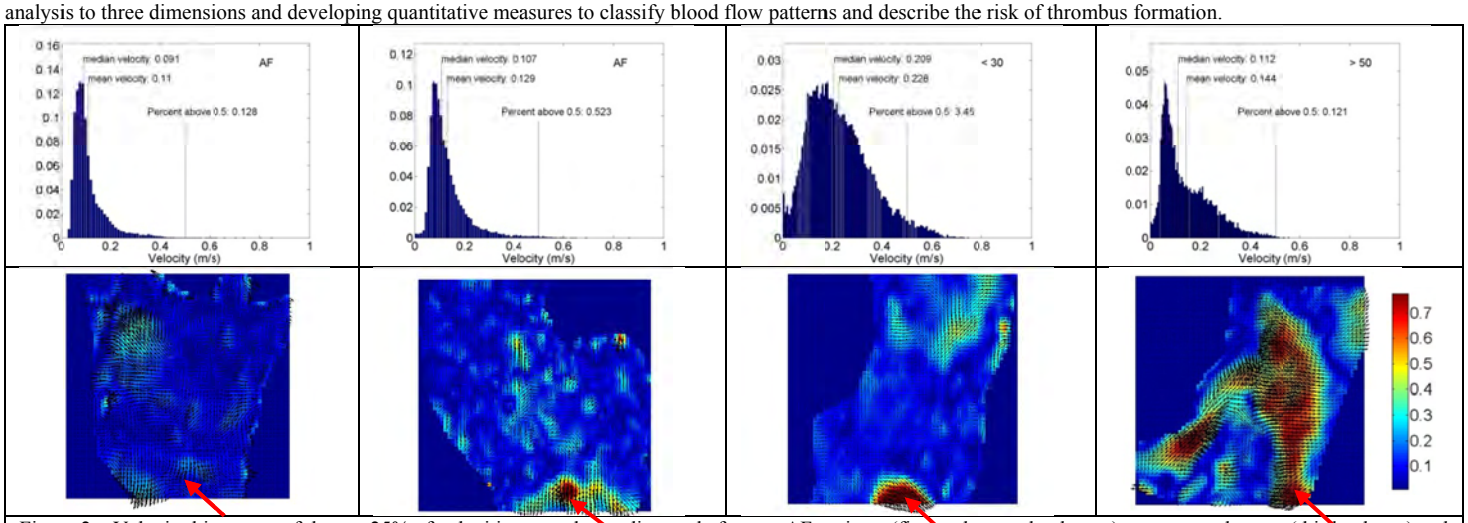


Figure 2 – Velocity histogram of the top 25% of velocities over the cardiac cycle for two AF patients (first and second columns), a young volunteer (third column) and an older volunteer (last column). The second row displays velocity vectors in the LA directly after the opening of the mitral valve (marked in red).

References: 1.Wolf et al., *Stroke* 22. 983-988 2. Fyrenius et al. *Heart* 86(4) 448-55 3. Markl et al. *J. Mag Res. Imaging* 17(4). 499-506

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