Analysis of flow vortices in the pulmonary artery of healthy normals and patients with PH with 4D flow MRI

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Target audience: Flow imaging, cardiovascular magnetic resonance.

Purpose: This work is a 4D flow study on the existence of vortices in blood flow in the pulmonary artery (PA) of healthy volunteers and patients with pulmonary hypertension (PH). The preliminary results show that, contrary to the published results in literature, vortices with back flow in the main pulmonary artery and also in the right and left PA are normally found in healthy patients and volunteers and that their existence in PH patients does not correlate with the mean pulmonary artery pressure (mPAP).

Introduction: PH is a disease of the right heart and pulmonary vasculature and is classified by an mPAP greater or equal to 25 mmHg. Time-resolved 3D magnetic resonance velocity mapping (4D flow) recently started to gain great interest for assessment of flow patterns in the blood circulation of the great vessels. It was applied to PH by Reiter et al[1], who concluded that manifest PH coincides with the appearance of a vortex of blood flow in the main PA with a high sensitivity and specificity, and that the relative period or lifetime of the vortex t_v correlates significantly with mPAP. It was also recently demonstrated that helical flow is normally present in the main PA and right PA of healthy volunteers and that a vortex associated with back flow was found in the PA of a patient with congenital heart disease[2]. The present study aims to assess the existence and formation of the vortices in a target population of 30 PH patients and 10 healthy volunteers.

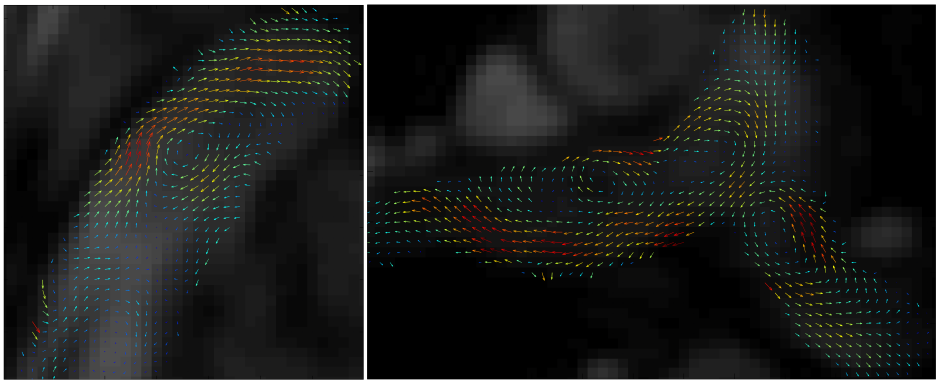

Figure 1: Velocity maps of blood circulation at late systole in the main PA (left: RVOT orientation) and right and left PA (right: axial orientation) of two healthy volunteers. The direction of a vector shows the average velocity direction over the pixel size whereas its length and color indicate the magnitude.

Materials and Methods: 20 subjects: 11 patients with PH (55 ± 28 y), 3 healthy patients (60 ± 18 y) and 6 healthy volunteers (32 ± 9 y) underwent 4D flow imaging of the pulmonary artery on a GE HDx 1.5T scanner (retrospective ECG-gated, spoiled gradient echo-based phase-contrast sequence with 4 point velocity encoding scheme). Imaging was performed during breath-hold in 2 different orientations (sagittal, RVOT, 30 cardiac phases and axial with 20 cardiac phases through the bifurcation of the main PA to RPAB and LPAB) with a slice thickness of 8 mm to cover the artery. The velocity encoding was set to 200 cm/s in all directions. The Dicom images were analyzed offline in Matlab to extract the 3 velocity components of each pixel. A region of interest including the PA was chosen on the magnitude image of each subject and colored arrows representing the velocity direction were added to the magnitude image of each cardiac frame. Only the vortices found in the sagittal plane were considered for the mPAP correlation. Their relative period of existence t_v (number of cardiac phases in which vortex is present divided by the total number of cardiac phases) were determined by a single observer blinded to the catheter results. The uncertainty in which time frames the vortex is formed and disappears led to the errors bars shown on Fig. 2.

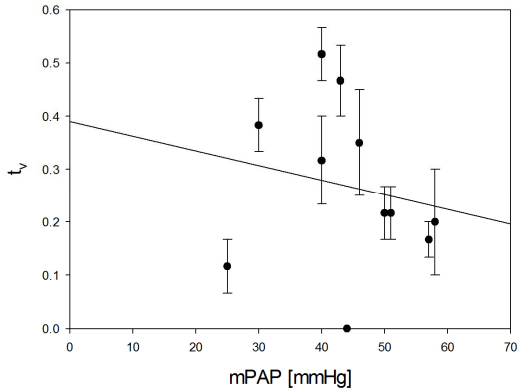

Figure 2: relative existence of the vortex t_v compared to the mPAP values of the 11 HP patients. The linear regression line gives a correlation coefficient of 0.04.

Results and discussion: Vortices were found in 2 of the 6 healthy volunteers and 2 of the 3 healthy patients (mPAP < 25 mmHg) leading to the preliminary conclusion that vortices of blood flow are present not only in PH patients but also in a significant percentage of healthy subjects. Examples of vortices in main PA but also in RPAB and LPAB in healthy subjects are shown in Fig. 1. Vortices were also found in 10 of the 11 PH patients. Their formation starts usually during late systole or just after RV valve closure. On figure 2, the relative existence of vortex is plotted against the mPAP at rest. Contrary to the previously published results[1], our data do not show any correlation ($r^2 \sim 0$), which suggests that the existence of a PA flow vortex is not a sensitive parameter for assessing the degree of PH severity. Further work will focus on increasing the number of subjects in PH and healthy volunteers groups and add a second independent observer in the data analysis.

References: 1 G. Reiter et al. Circulation: Cardiovascular Imaging, vol. 1: 23-30, 2008; 2 P. Bächler et al. Magnetic Resonance Imaging, in press, 2012