Abnormal Pulmonary Flow is Associated with Impaired Right Ventricular Coupling in Patients with COPD

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BACKGROUND

- Cor Pulmonale or right ventricular (RV) dysfunction due to pulmonary disease is an expected complication of COPD resulting from increased afterload mediated by hypoxic pulmonary vasoconstriction as well as the destruction of the pulmonary vascular bed.
- Early detection of elevated RV afterload has been previously demonstrated by visualization of abnormal flow patterns in the proximal pulmonary arteries.
- Prior quantitative analysis of helicity in the pulmonary arteries of pulmonary hypertension patients has demonstrated a strong association with measurements of RV afterload.
- We hypothesized that patients with COPD have abnormal pulmonary flow hemodynamic indices as evaluated by 4D-Flow MRI associated with abnormal RV function and pulmonary artery stiffness

METHODS

- Patients with COPD (n=15) (65yrs ± 6) and controls (n=10) (58yrs ± 9) underwent 4D-flow MRI to calculate helicity (Figure 1A).
- The helicity, a dot product of vorticity and velocity vector fields, was calculated in 2 segments: 1) the main pulmonary artery (MPA) and 2) along the RV outflow tract (RVOT) – MPA axis (**Figure 1**)
- Main pulmonary arterial stiffness was measured using the relative area change (RAC).

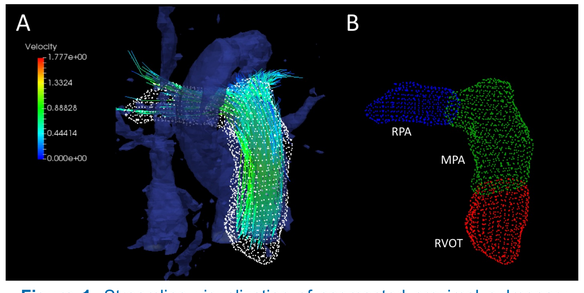

Figure 1. Streamline visualization of segmented proximal pulmonary arteries from 4D-Flow MRI derived MR angiography. B, The evaluated segments included the RVOT and MPA.

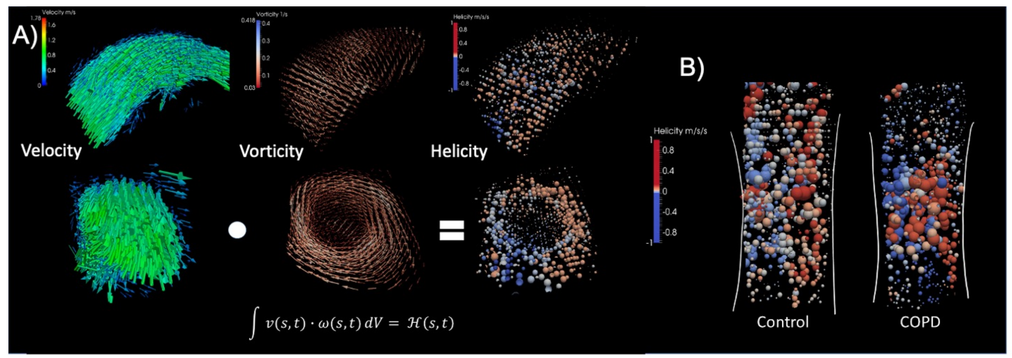

Figure 2A. Visualization of velocity and vector fields. The dot product of the two 3Dfeilds yields a scalar value of helicity, here depicted along the MPA length. **2B** Comparative difference between the pulmonary arterial tracts herein depicted in a healthy control subject and a subject with COPD. One can appreciate the global reduction in helicity along the MPA in COPD patient.

RESULTS

- COPD patients had decreased helicity relative to healthy controls in the MPA (19.4±7.8 vs 32.8±15.9 s^{-2}, P=0.007) (Table 1). Additionally, COPD patients had reduced helicity along the RVOT-MPA axis (33.2±9.0 vs 43.5±8.3 s^{-2}, P=0.010).
- The helicity measured in the MPA was associated with RV end-systolic volume (R=0.59, P = 0.002), RVEF (R=0.631, P<0.001), RAC (R=0.61, P=0.001). The combined helicity along the MPA-RVOT axis was associated with RVEF (R=0.74, P<0.001), RVESV (R=-0.57, P=0.004), and RAC (R=0.42, P=0.005).

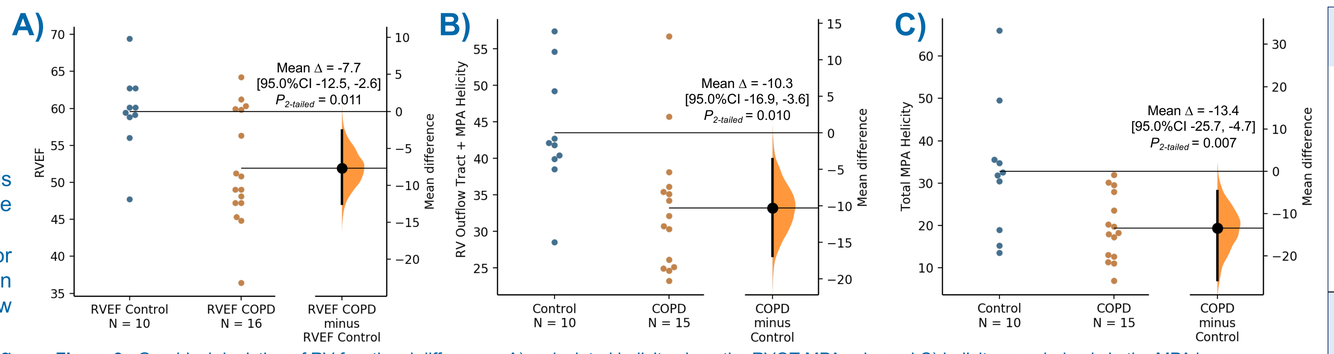

Figure 3. Graphical depiction of RV functional differences A), calculated helicity along the RVOT-MPA axis, and C) helicity sampled only in the MPA lumen.

Table 1 Correlations of Helicity in subjects with COPD and Controls

	MPA Helicity	MPA-RVOT Helicity
RVEF	R=0.63, P<0.01	R=0.5485, P<0.01
RVESV	R=-0.59, P<0.01	R=-0.57, P<0.57
RVEDV	R=-0.30, P=0.16	R=-0.14, P=0.51
RV SV	R=0.14, P=0.53	R=0.36, P=0.084
VVCR	R=-0.61, P<0.01	R=-0.74, P<0.01
RV CO	R=-0.22, P=0.30	R=-0.01, P=0.95
RV CI	R=-0.22, P=0.30	R=-0.17, P=0.43
RV HR	R=-0.40, P<0.05	R=-0.40, P=0.05
RAC	R=0.52, P=<0.01	R=0.65, P<0.01
6-MWT	R=0.46, P=0.08	R=0.42, P=0.11

Correlations are reported as R values, with corresponding P values. Definition of abbreviations: ; RV EF, right ventricular ejection fraction; RVESV, right ventricular end systolic volume; RVEDV, right ventricular end diastolic volume; RV SV, right ventricular stroke volume; RV CO, right ventricular cardiac output; RV CI, right ventricular cardiac index; HR, heart rate VVCR, ventricular-vascular coupling ratio; RAC, relative area change; 6-MWT, six-minute walk test; MPA, main pulmonary artery; MPA-RVOT, main pulmonary artery-right ventricle outflow tract.

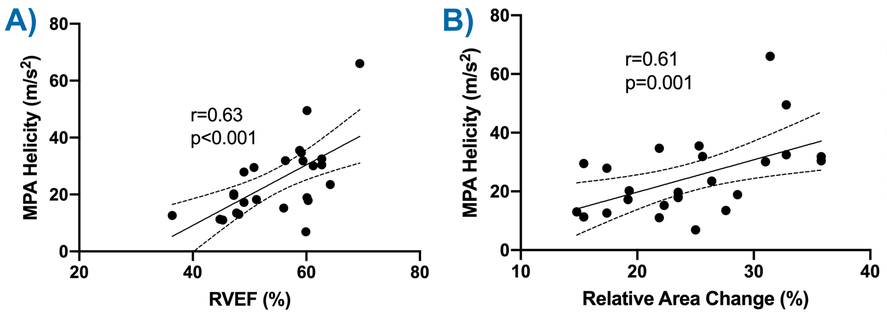

Figure 4. Graphical visualization of the observed relationship between helicity measured in the MPA and **A)** the RV EF and **B)** relative area change measured in the MPA. Good association with the measurement of RV function and pulmonary arterial stiffness suggests that helicity might serve as a marker of ventricular-vascular coupling in patients with COPD.

CONCLUSION

- Patients with COPD show quantitatively abnormal flow hemodynamics, when compared with healthy controls, as assessed by 4D-Flow MRI.
- A strong association between helicity along the MPA-RV outflow tract axis and RV function suggests that 4D-Flow MRI might be a sensitive tool in evaluating RV-pulmonary arterial coupling in COPD.