



Irregular Blood Flow Patterns in the Development of Pulmonary Hypertension

V. Kheyfets, M. Schafer, J. Smyser, A. Honeyman, J. Browning, J. Hertzberg, J. Schroeder, K. Hunter, B. Fenster, R. Shandas



University of Colorado
Anschutz Medical Campus

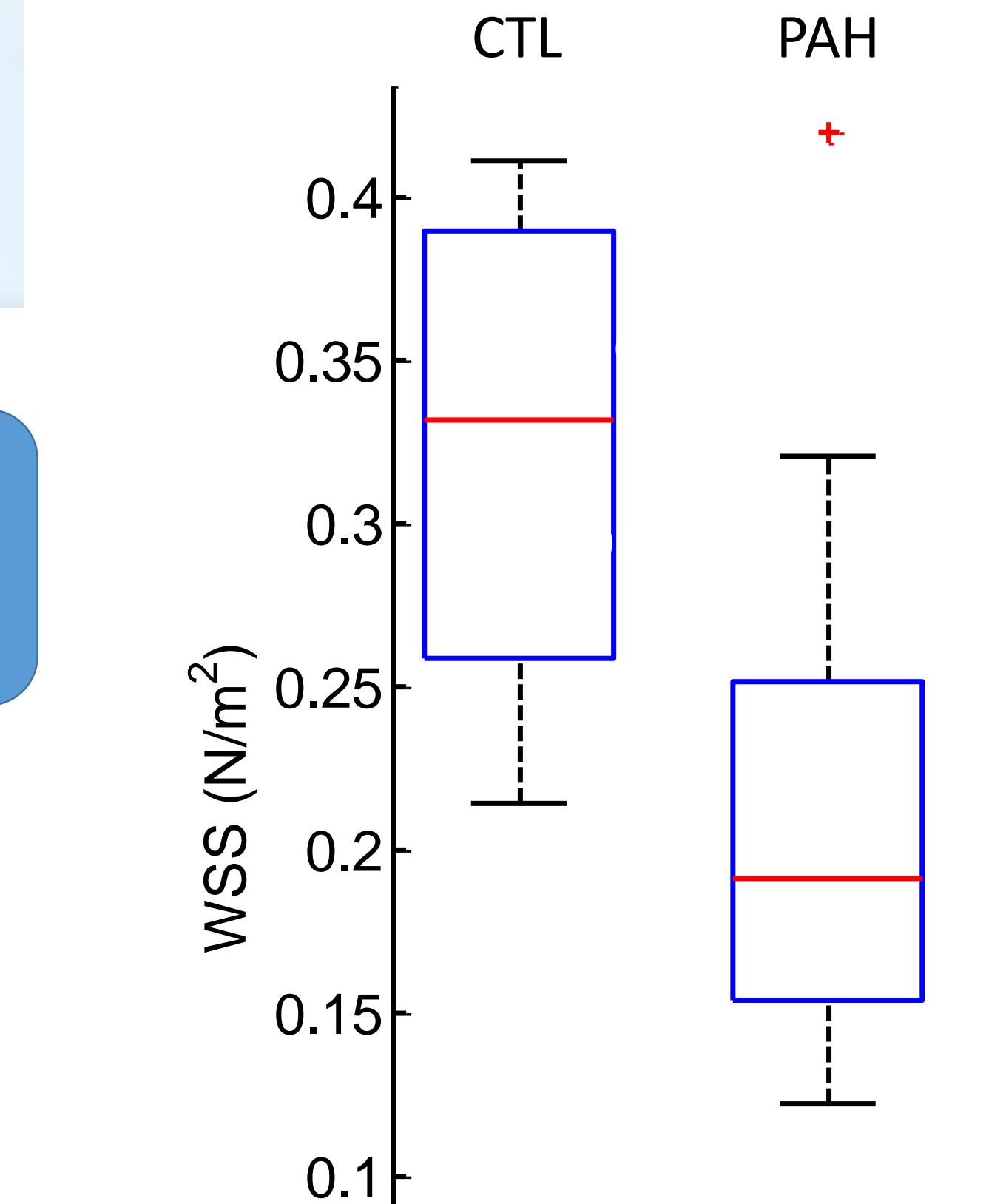


National Jewish Health®
Science Transforming Life®

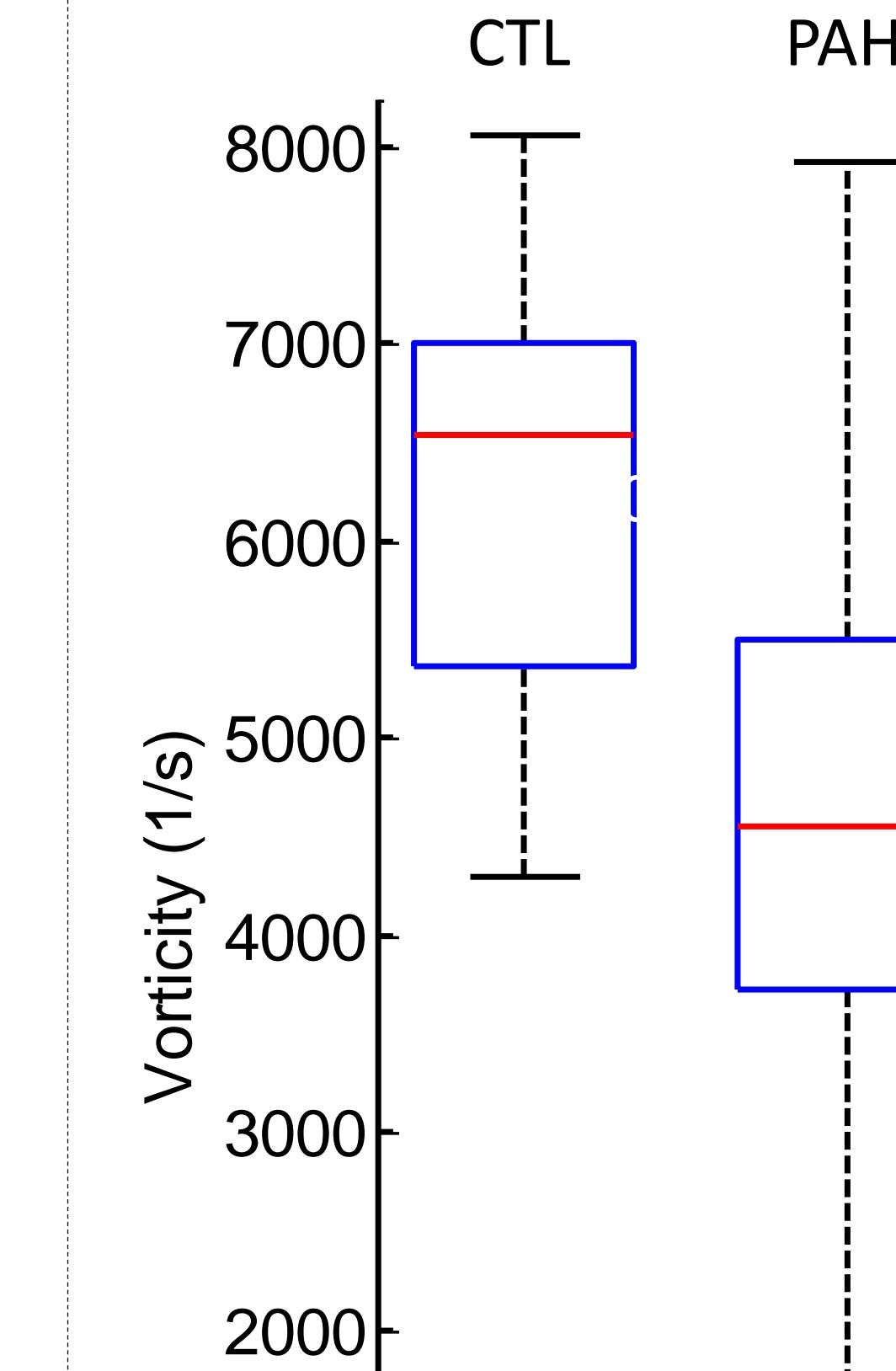
Results

Flow markers are changed in PH

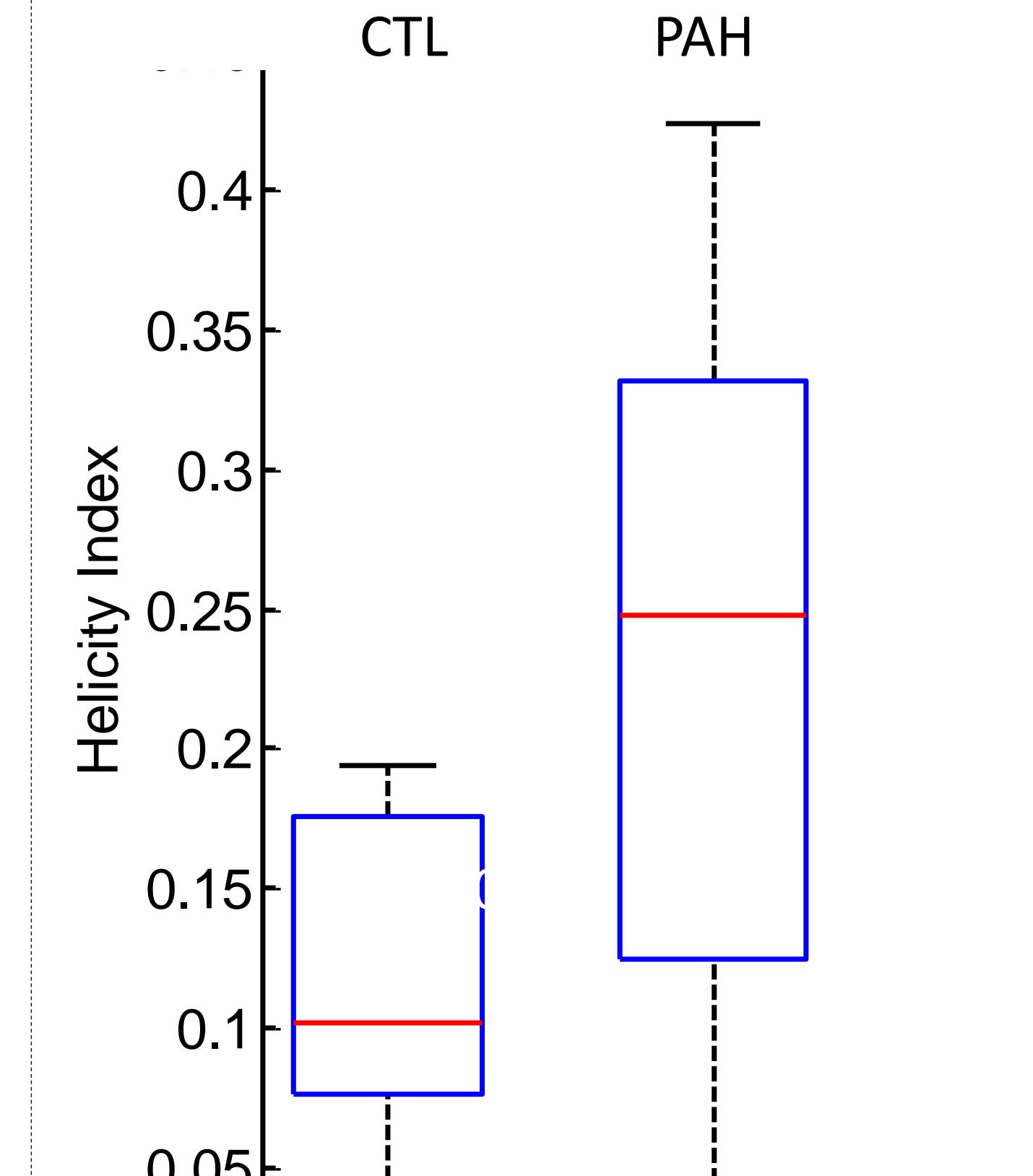
WSS



Vorticity



Helicity



Methods

Demographics

Dataset: 22 Patients w/ PAH symptoms:

Each Patient in
DATASET

Flow Kinematics

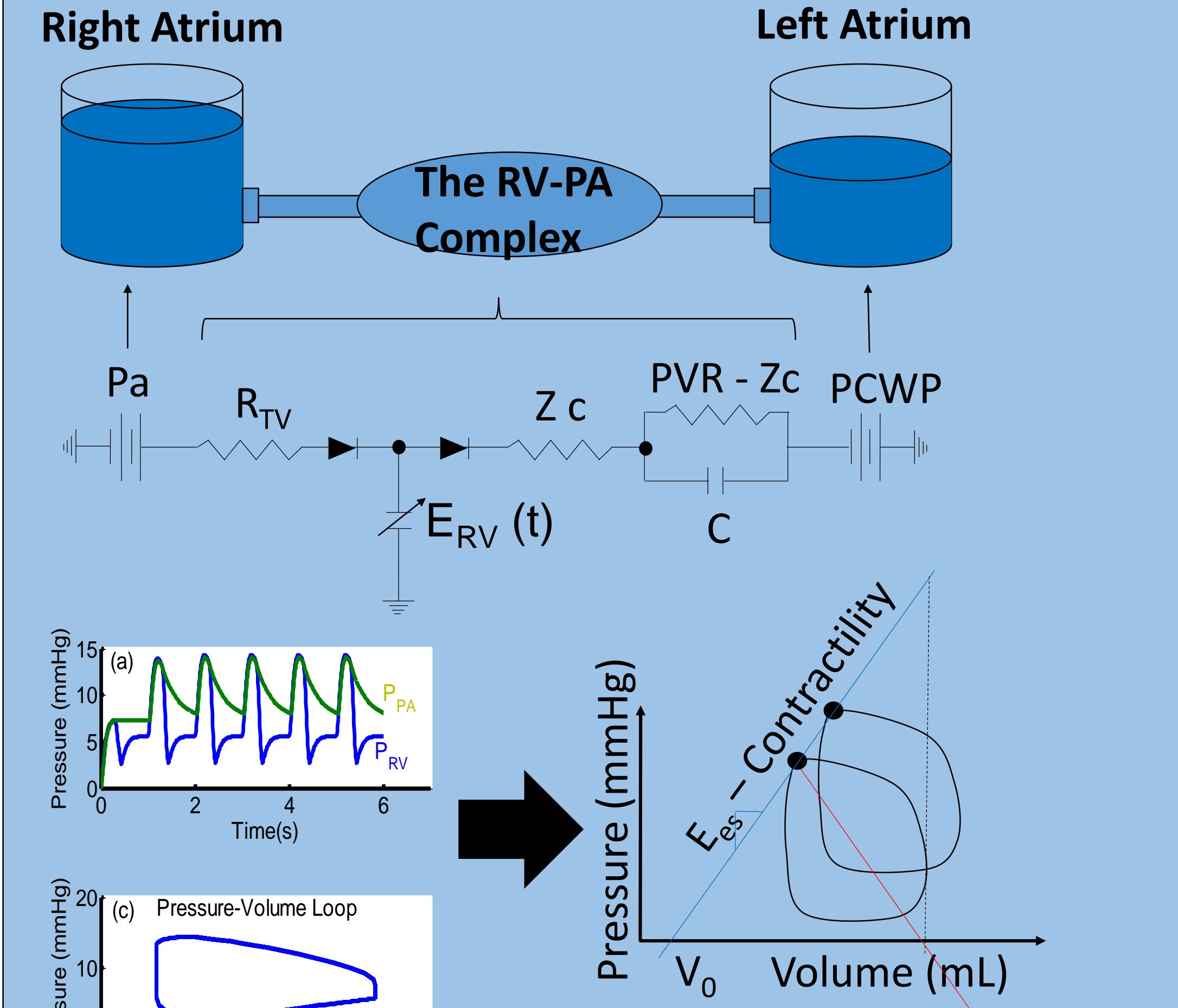
4D MRI (5CTL vs. 17PH)

- Data analyzed at peak systole
 - Magnitude of the Vorticity Vector ($|\vec{\omega}|$)
 - Helicity Index = $\frac{1}{N_k} \sum_{k=1}^K \text{Sum over entire mesh} \left| \frac{\vec{\omega} \cdot \vec{v}}{|\vec{\omega}| |\vec{v}|} \right|$
 - Wall Shear Stress: $\tau = \mu (Ht) \frac{du}{dy}$

RV-PA Coupling

- Traditional Hemodynamics (3CTL vs. 17 PH)
 - mPAP
 - PVR
 - Work = CO*mPAP
 - PP

RV-PA Coupling Assessment



$$VVC = \frac{E_{es} \text{ (Contractility)}}{E_a \text{ (Afterload)}}$$

Proximal Distal Pulmonary Arterial Coupling

- Impedance mismatch between the proximal and distal vasculature: Index of Wave Reflection, Γ

$$PAP_{mean} = \frac{[(1 + D \cdot PCWP)^5 + 5D \cdot PVR' \cdot CO]^{1/5} - 1}{D}$$

$$Z_c = \sqrt{\frac{\rho Eh}{2\pi^2 R^5}} \rightarrow \sqrt{\frac{1}{\rho D}} = \sqrt{\frac{Eh}{2\rho R}} \rightarrow Z_c = \frac{\rho}{\pi R^2} \sqrt{\frac{1}{\rho D}}$$

$$F = \frac{PVR - Z_c}{PVR + Z_c}$$

- Clinical Translation:
 - Flow patterns, available from 4D MRI, are indicative of vascular and ventricular function
 - Need larger CTL and PH samples

Research Translation

- Flow patterns are associated with RV function, distal constriction (resistive afterload), and proximal remodeling (reactive afterload)
- Helical flow patterns could have implications on bulk transport efficiency
- WSS ↔ Endothelial Function ↔ Vascular Function ↔ RV-PA Function

Acknowledgements

- NIH NHLBI 5 T32 HL072738-10
- Butcher Foundation Award
- NIH RO1 HL 114753
- NIH K24 HL081506

Discussion

