



Mass General Brigham

Fractal Dimension Estimation Using Box-Counting to Quantify CT-Based Pulmonary Vascular Tree Simplification

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Overview

Pulmonary Arterial Hypertension (PAH)

- Characterized by pulmonary vascular pruning
- Diagnosed by right heart catheterization
 - Invasive procedure
 - Requires specialized equipment

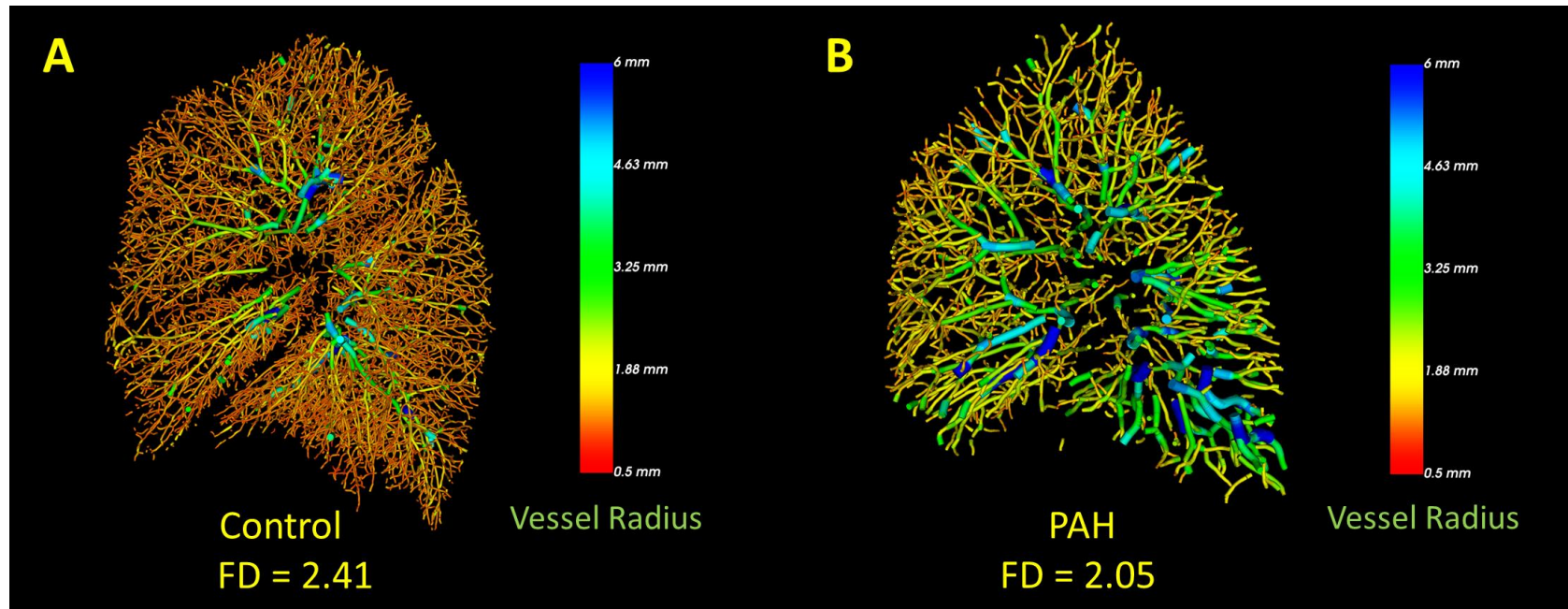
There is a need for a non-invasive and scalable method of diagnosing and monitoring pulmonary hypertension.



Overview

Fractal Dimension

- Measure of self-similarity, or complexity
- Calculated using box-counting method
- More “complex” images tend to have higher fractal dimension



Analysis

Previous studies have produced mixed results^{1, 2}

Two Variables to Consider

- Separation of Artery / Vein
- Scale of Analysis
 - Small Scale: Finer details
 - Large Scale: Coarser details

	Control	PAH
N	37	42
Female	28	35
Age	43 (44-64)	64 (52-74)
mPAP (mmHg)	18 (14-20)	42 (35-59)
PVR (Wood Units)	1.2 (1.0-1.7)	72 (5.6-9.8)
Lung Volume	3.7 (2.7-4.4)	3.1 (2.7-3.9)

1. Haitao S, Ning L, Lijun G, Fei G and Cheng L. Fractal Dimension Analysis of MDCT Images for Quantifying the Morphological Changes of the Pulmonary Artery Tree in Patients with Pulmonary Hypertension. Korean J Radiol. 2011;12:289-296.

2. Moledina S, de Bruyn A, Schievano S, Owens CM, Young C, Haworth SG, Taylor AM, Schulze-Neick I and Muthurangu V. Fractal branching quantifies vascular changes and predicts survival in pulmonary hypertension: a proof of principle study. Heart. 2011;97:1245-9.



Results

	Control (N = 37)	PAH (N = 42)	p-value
Total	2.31 (2.34-2.41)	2.28 (2.23-2.31)	0.005
Total – Large Scale	2.37 (2.34-2.41)	2.36 (2.33-2.39)	0.10
Total – Small Scale	2.39 (2.38-2.42)	2.38 (2.35-2.41)	0.14
Arterial	2.17 (2.16-2.19)	2.16 (2.12-2.20)	0.10
Arterial – Large Scale	2.21 (2.20-2.22)	2.22 (2.19-2.25)	0.74
Arterial – Small Scale	2.1 (2.06-2.14)	2.13 (2.10-2.17)	0.02
Venous	2.10 (2.06-2.14)	2.02 (2.0-2.08)	<0.0001
Venous – Large Scale	2.12 (2.10-2.16)	2.07 (2.03-2.11)	<0.0001
Venous – Small Scale	2.0 (1.97-2.01)	1.96 (1.92-2.0)	0.001

Total Vasculature

- Significantly lower FD in PAH only when not limiting scale

Arteries

- Significant only in small scale

Veins

- Significant regardless of scale



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Conclusions

- Reveals more complex picture when taking methodology into account
 - Arterial / Veinous Separation
 - Scales of Analysis
- Multifractal nature of pulmonary tree
- Differential changes throughout PAH
 - Proximal Dilation
 - Distal Pruning

Moving Forward!

- More extensive search using fractal dimension
- Compare with other measures of complexity





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