High resolution CT-based characterization analysis of idiopathic pulmonary fibrosis

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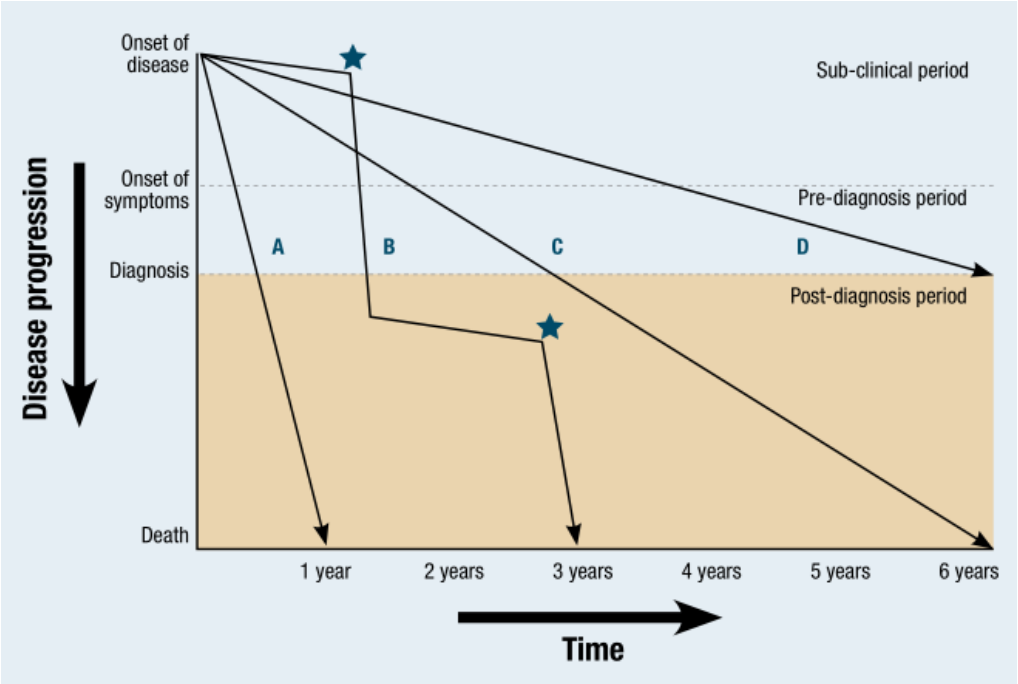
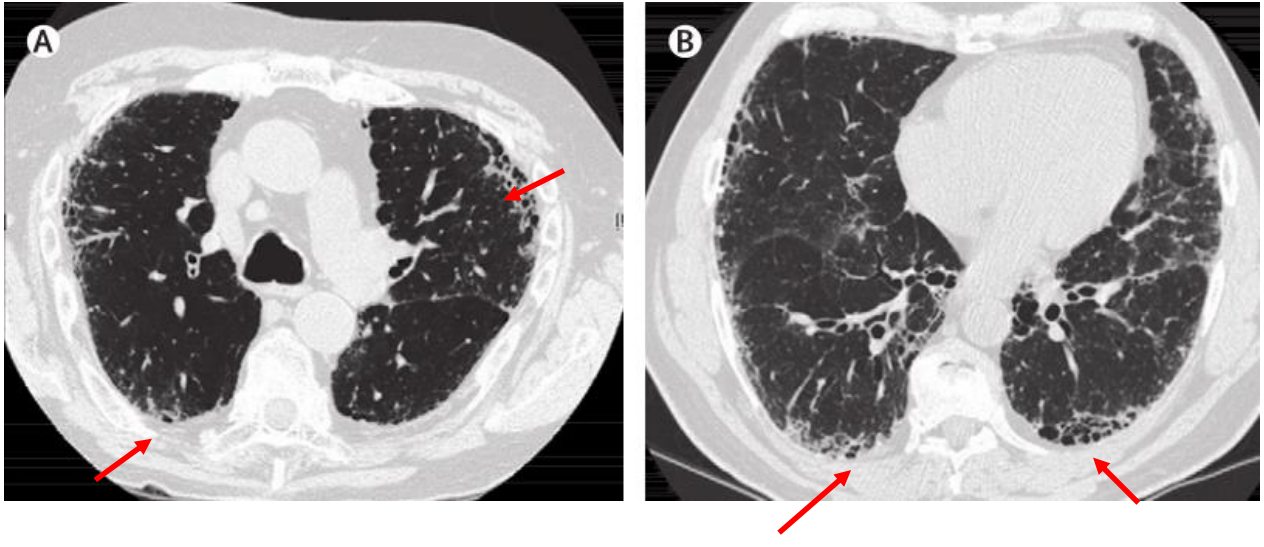
Background

- Idiopathic pulmonary fibrosis (IPF) is a chronic and life-threatening disease
- Cause is unknown
- Etiology remains elusive
- Progression is variable and unpredictable



Background

- HRCT is an essential tool in evaluating lung disease
- Associated with the presence of a usual interstitial pneumonia (UIP) pattern on HRCT (ATS/ERS criteria)
- Honeycomb, reticular, ground-glass



Aim

Currently published work:

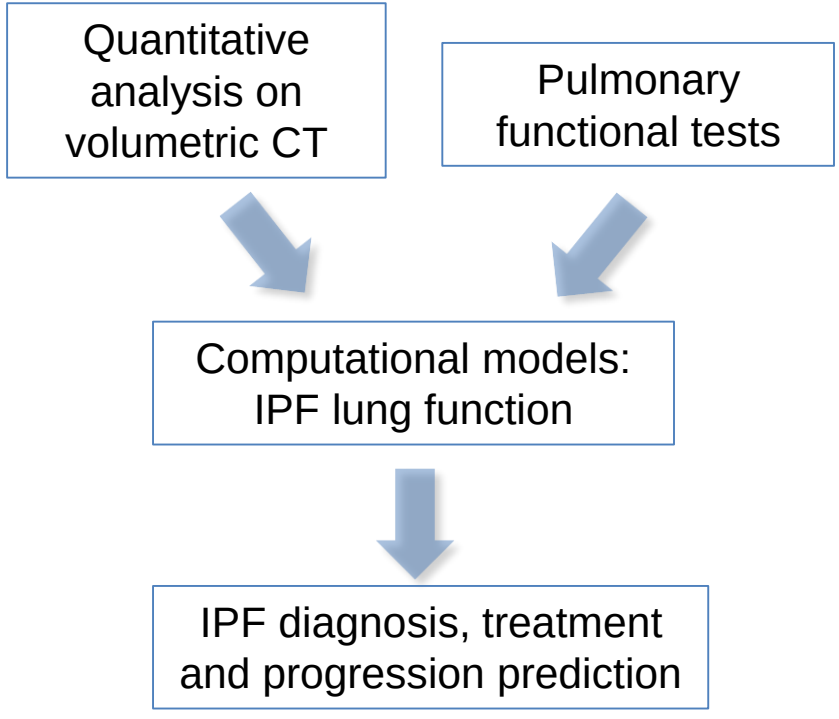
- Quantitative analysis of radiological images
- Clinical functional measurements

Radiological images may be not sufficient enough to explain the decline of lung function

Limited research into combining spatial data with functional data.

No established quantitative tools to assess the progression of IPF

Aim



Imaging and clinical data

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Clinical data assessed in this study	
Age (years)	43-82
Females/Males	3/5
Slice thickness (mm)	1.25-3.00
Interval between scans (months)	5-20
Slice resolution	512x512
Number of slices	65-160

The clinical data used in this study comprised HRCT images and pulmonary function tests obtained from 8 patients diagnosed with IPF at Auckland City Hospital, Auckland, New Zealand.

5 patient → 1 time point
1 patient → 2 time point
2 patient → 3 time point

Pulmonary parenchymal classification

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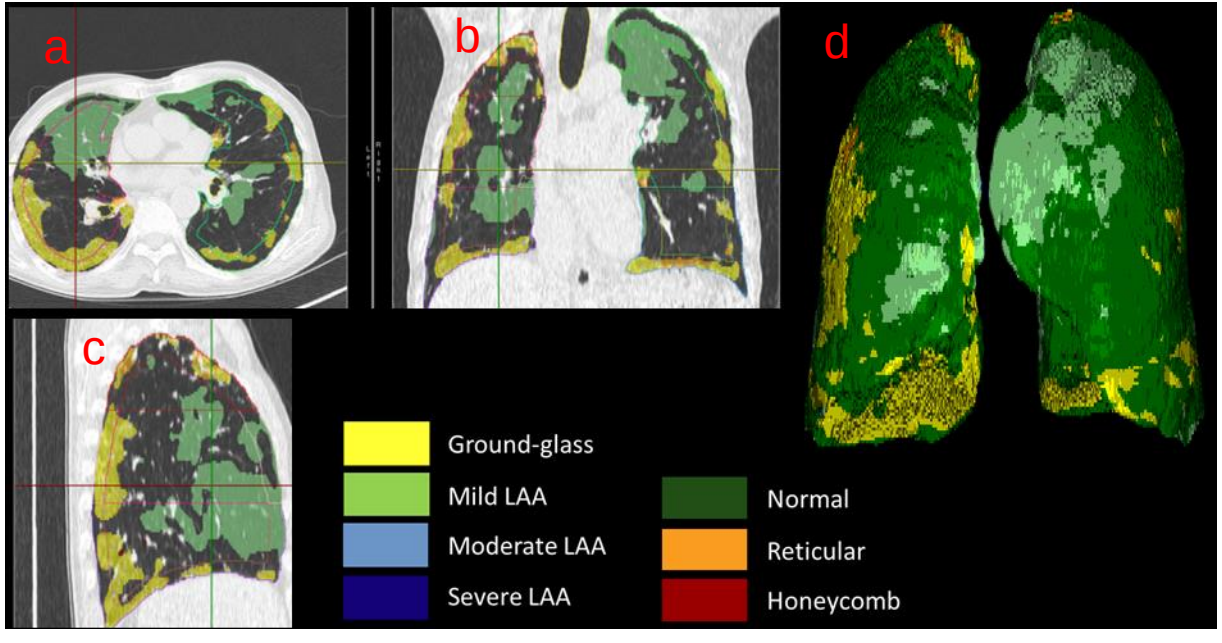
CALIPER (Computer-Aided Lung Informatics for Pathology Evaluation and Ratings) software. Mayo Clinic (Rochester, MN, USA)

Each parenchymal voxel was classified into the following characteristic CT patterns: normal (N), reticular (R), honeycomb (HC), ground-glass (GG), mild low attenuation areas (LAA), moderate LAA and severe LAA. Emphysema : Hounsfield Unit is under -950.



Color labelled classification result of case 7 on IPF HRCT by CALIPER. (a) Transverse plane. (b) Coronal plane. (c) Sagittal plane. (d) 3D color labelled lung.

By. Brian Bartholmai

Normalization of classified data

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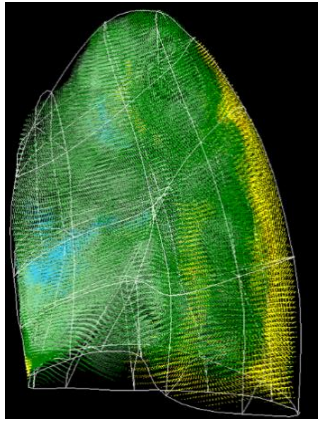
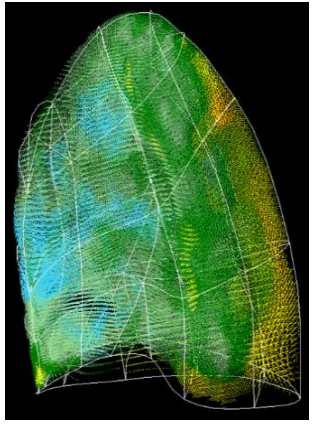
- Lung mesh : bi-cubic Hermite finite element surface mesh (left lung: 35 nodes and 44 elements; right lung: 50 nodes and 62 elements)

- Classified data mapping : statistical shape model (SSM), principal component analysis (PCA)

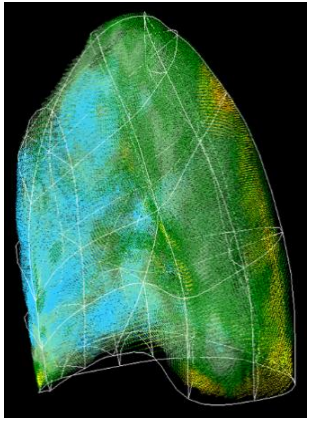
Time point 1



Time point 2

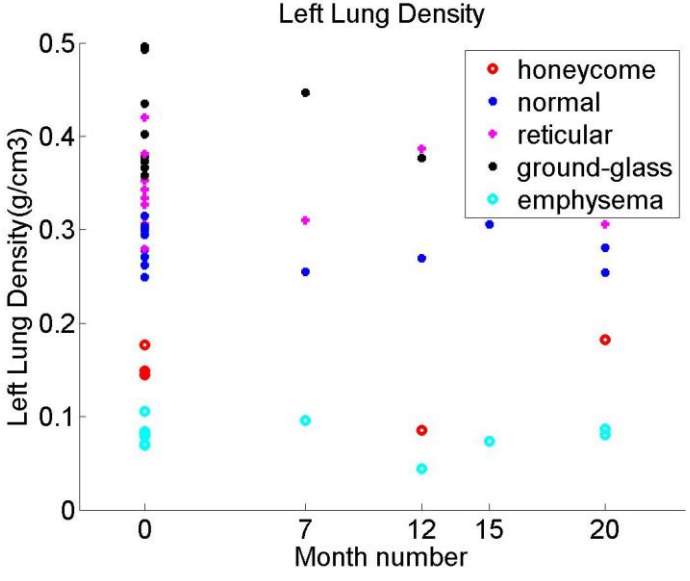


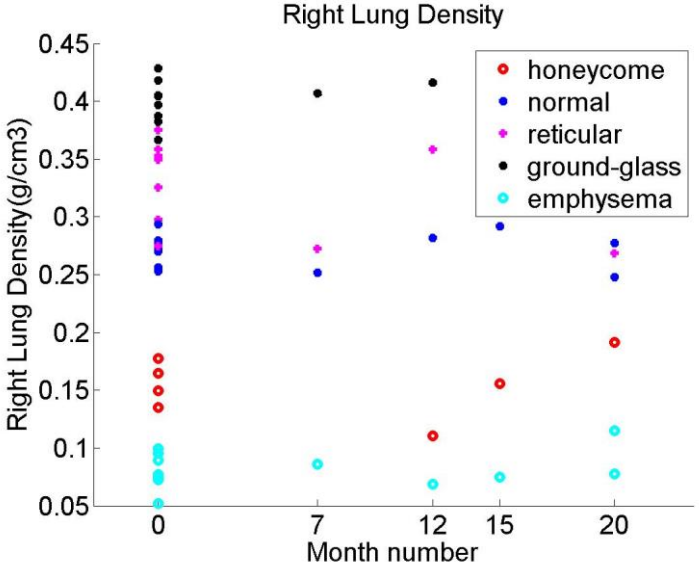
Time point 3



Density analysis

- Fibrosis usually has a consistently higher tissue density (0.34/0.41 for reticular/ground-glass) compared to normal tissue (0.27) over time
- In contrast, emphysema has lower density (0.078)





Spatial distribution analysis

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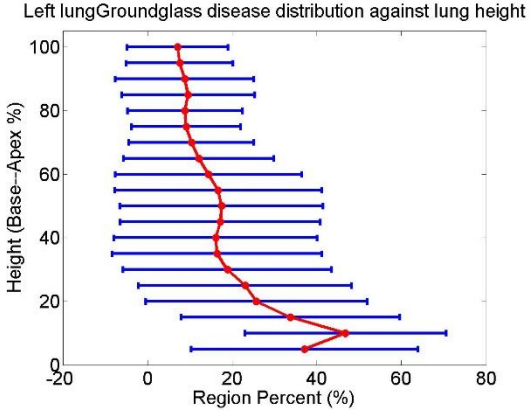
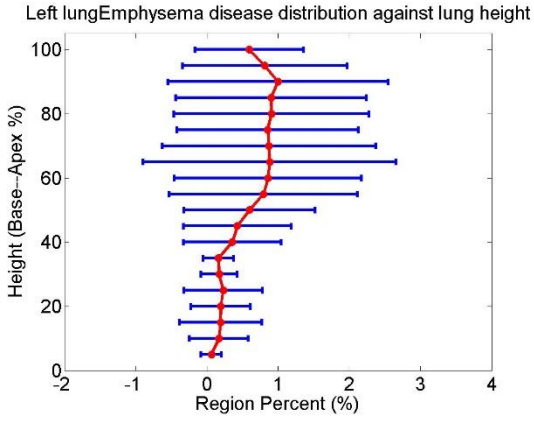
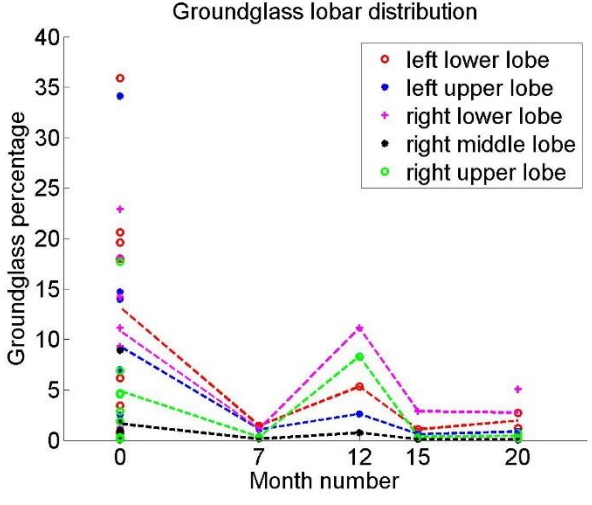
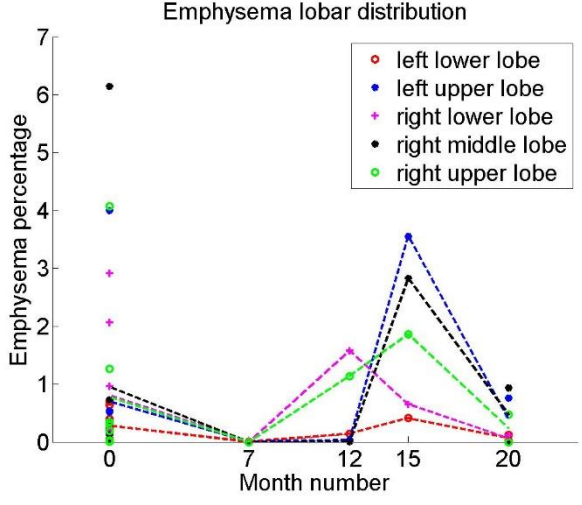
Ground-glass



Emphysema







- Fibrosis mostly located in lower lobes (72%, 58%, 65% for honeycomb, reticular, ground-glass)
- Emphysema mostly located in upper lobes (73%)

SSM based shape analysis

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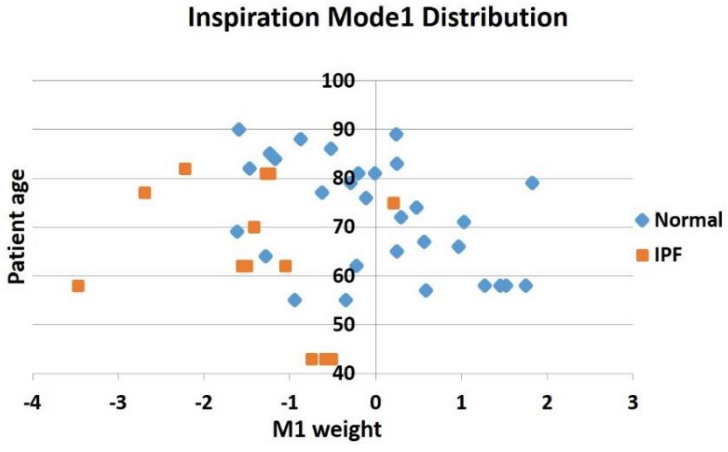
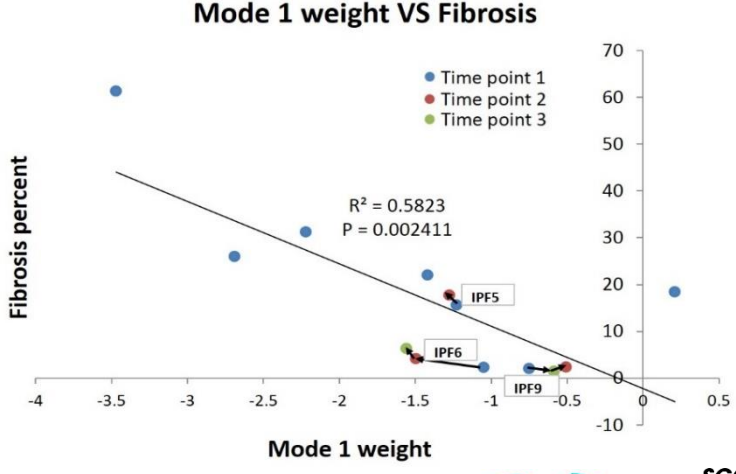
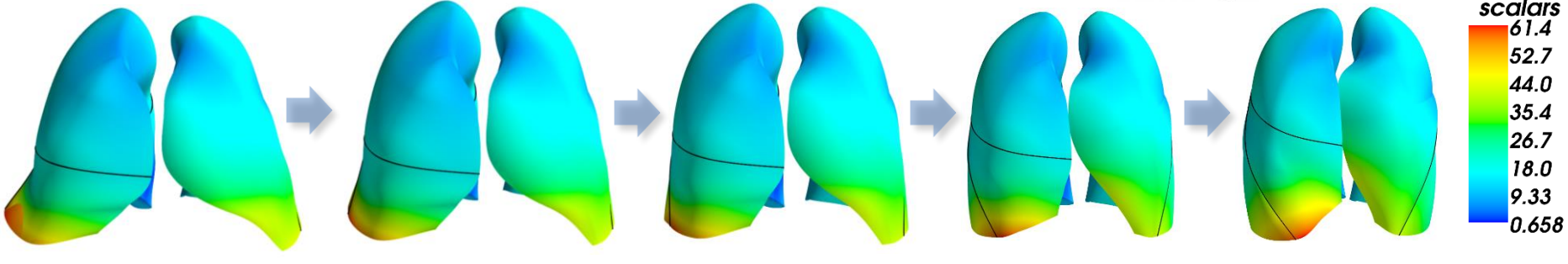
Training data collection (35 older normal) → Principle component shape feature analysis → Statistical shape model construction → Specific subject projection







Mode1 -3 Mode1 -2 Mode1 -1 Mode1 1 Mode1 3

IPF patient-specific airway tree geometry

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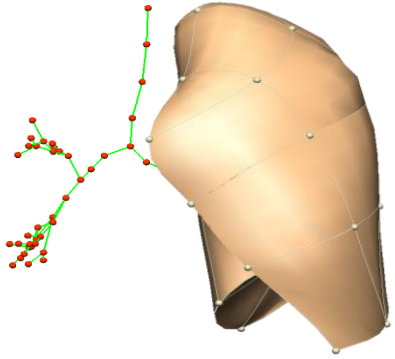
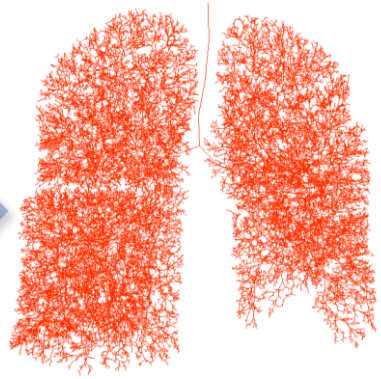
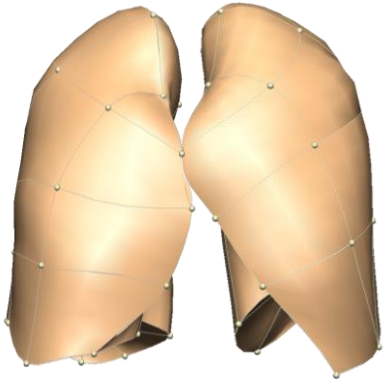


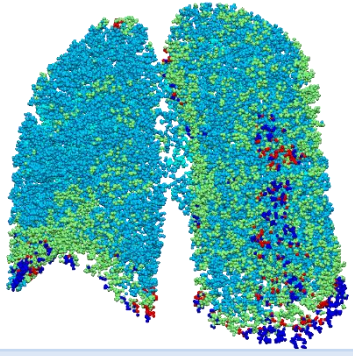
Manually digitize upper airway



Generate full airway tree of time point 1



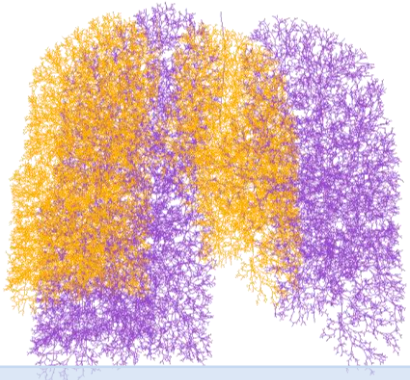
Map first airway tree to other time points



Label each terminal acinar unit with different CT patterns

Disease spatial distribution

Disease percentage against gravitational height



Scale the airway tree (length and radius) to FRC volume

IPF patient-specific ventilation analysis

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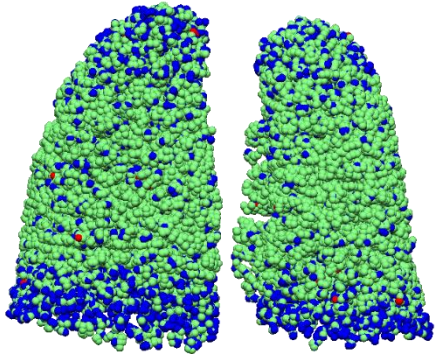
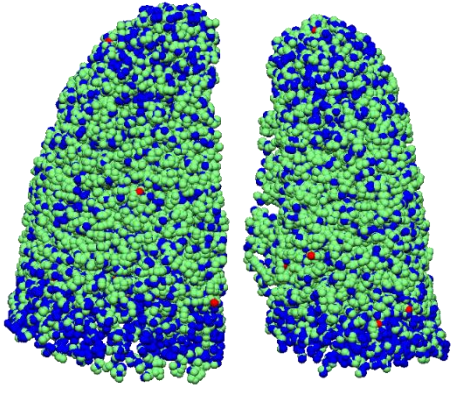
Forced inspiration

Reference FRC –TLC: set muscle pressure

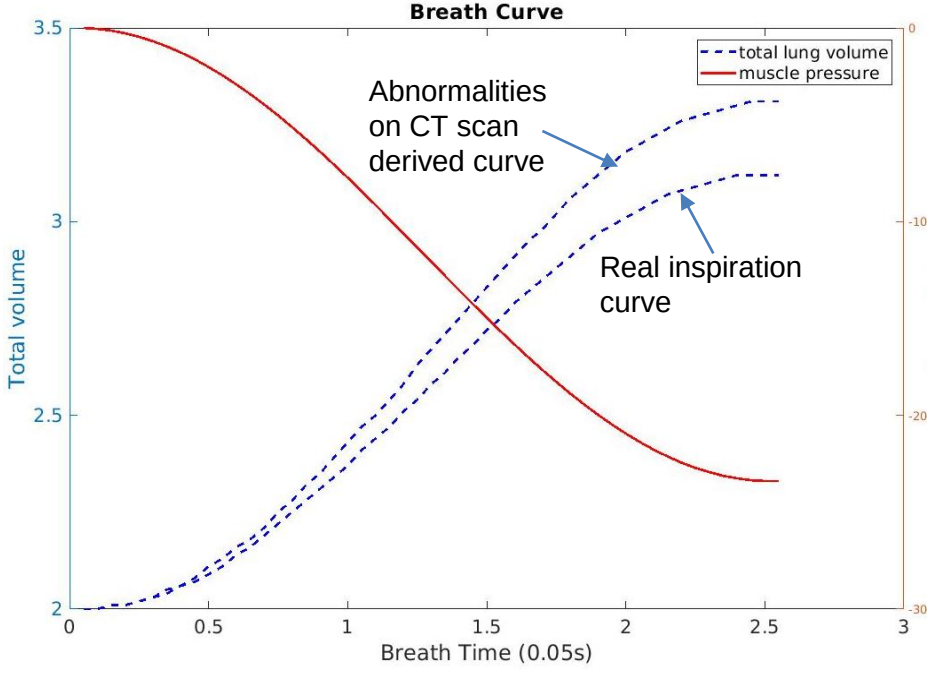
Real FRC –TLC: set real abnormality distribution



Fibrosis: 17.64%(from CT)



Fibrosis: 29.75%



- abnormalities on volumetric data are not sufficient to explain increased lung stiffness

IPF patient-specific gas exchange analysis

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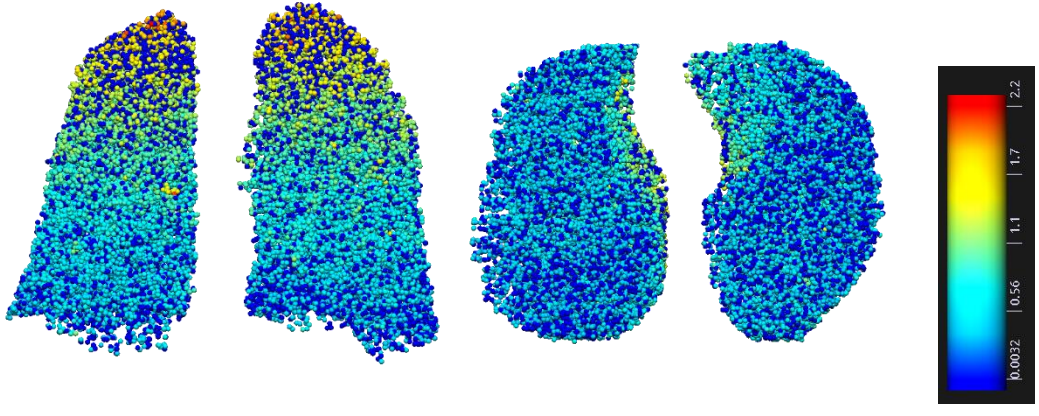
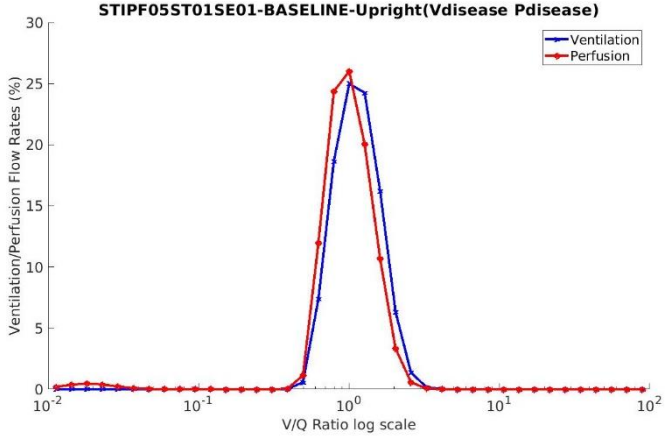
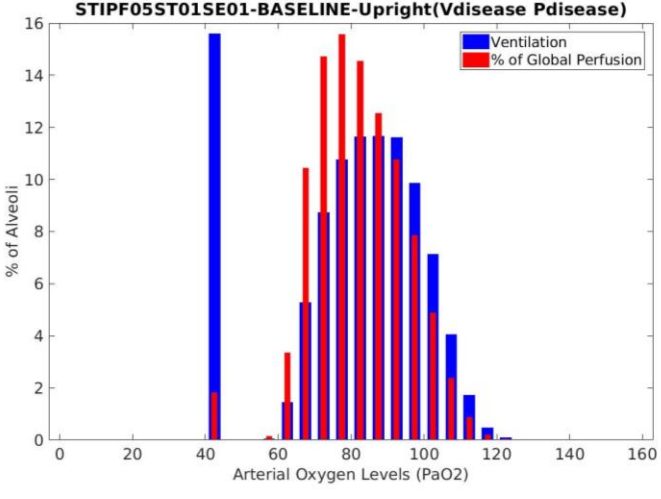
Perfusion analysis:

- parameterize the model inputs
- generate vessel geometry
- reduce the vessel radius of disease labelled region



V/Q ratio distribution





Conclusion

- Combine quantitative characterization extracted from volumetric CT with PFTs to parameterize the computational model
- Simulate basic lung function
- Shape difference between IPF lungs and old normal lungs (PCA based SSM)
- The decline of lung function could not be fully explained by radiological tissue abnormalities

Thank you

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