CT imaging in Asthma

Sang Hyuk Kim | Korea University Guro Hospital

Contents

Why CT imaging in Asthma
What can we get from the CT
How to use CT imaging in Clinic

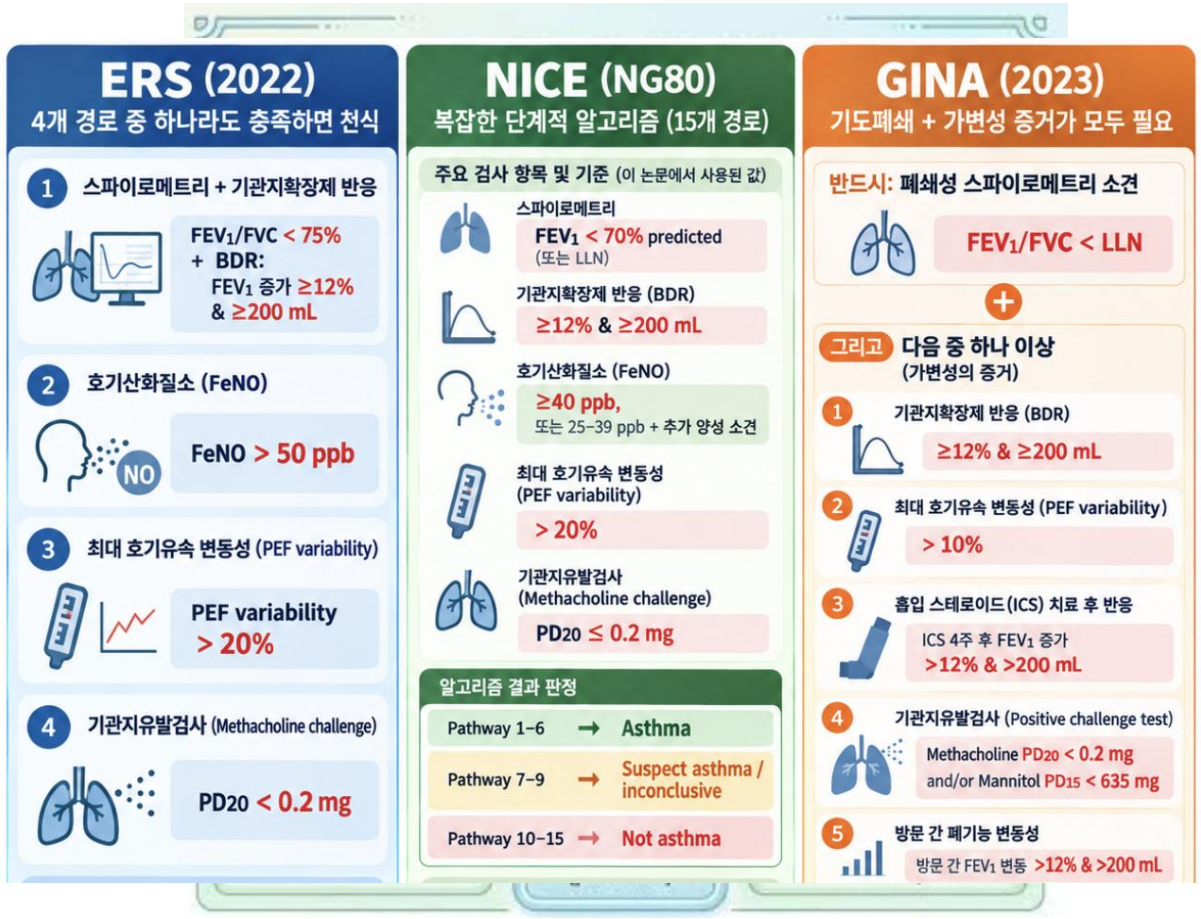
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Is Physiologic Diagnosis Enough?



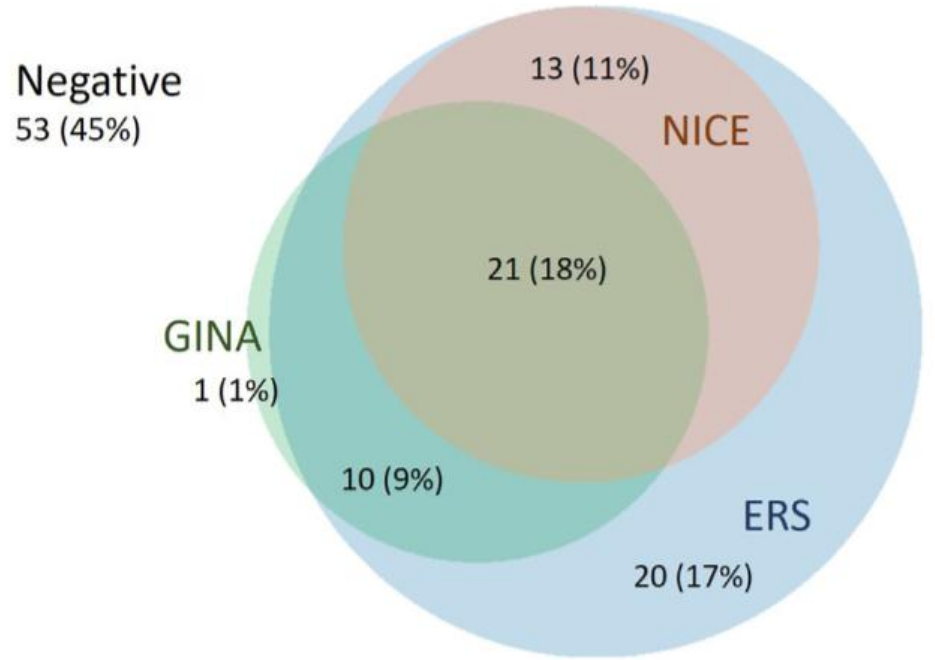


Fig. 1: Venn diagram showing concordance of, ERS, NICE and GINA guidelines for the diagnosis of asthma in 118 adults with respiratory symptoms.

GINA 2026; Image (Asthma Pulmo Egy. Group); Simpson et al. eClinicalMedicine 2024; Image generated by chat GPT

Why do we need imaging

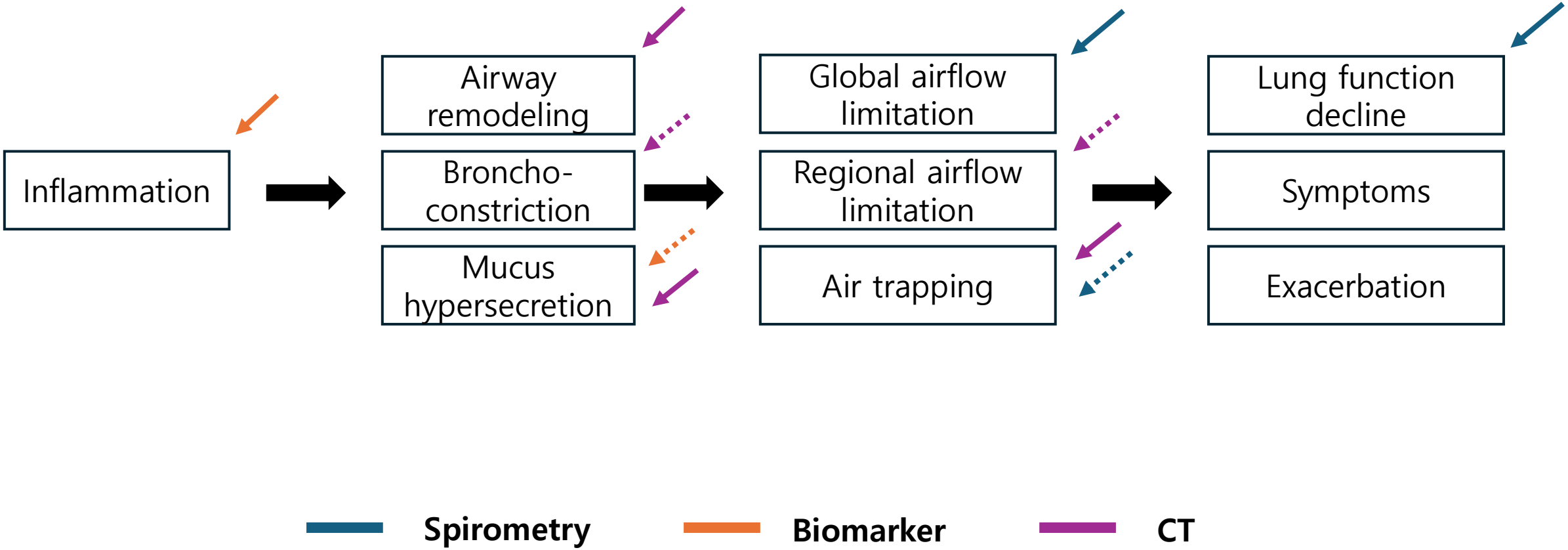
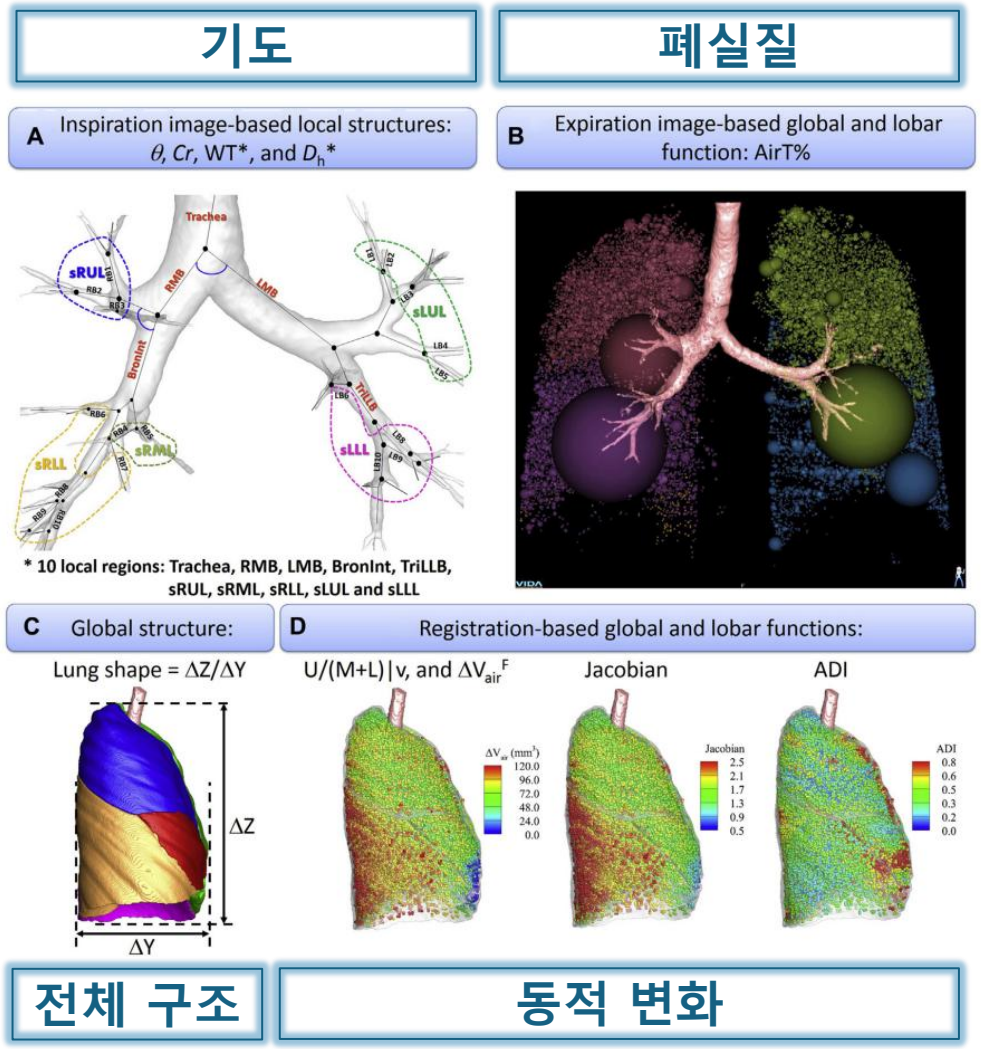


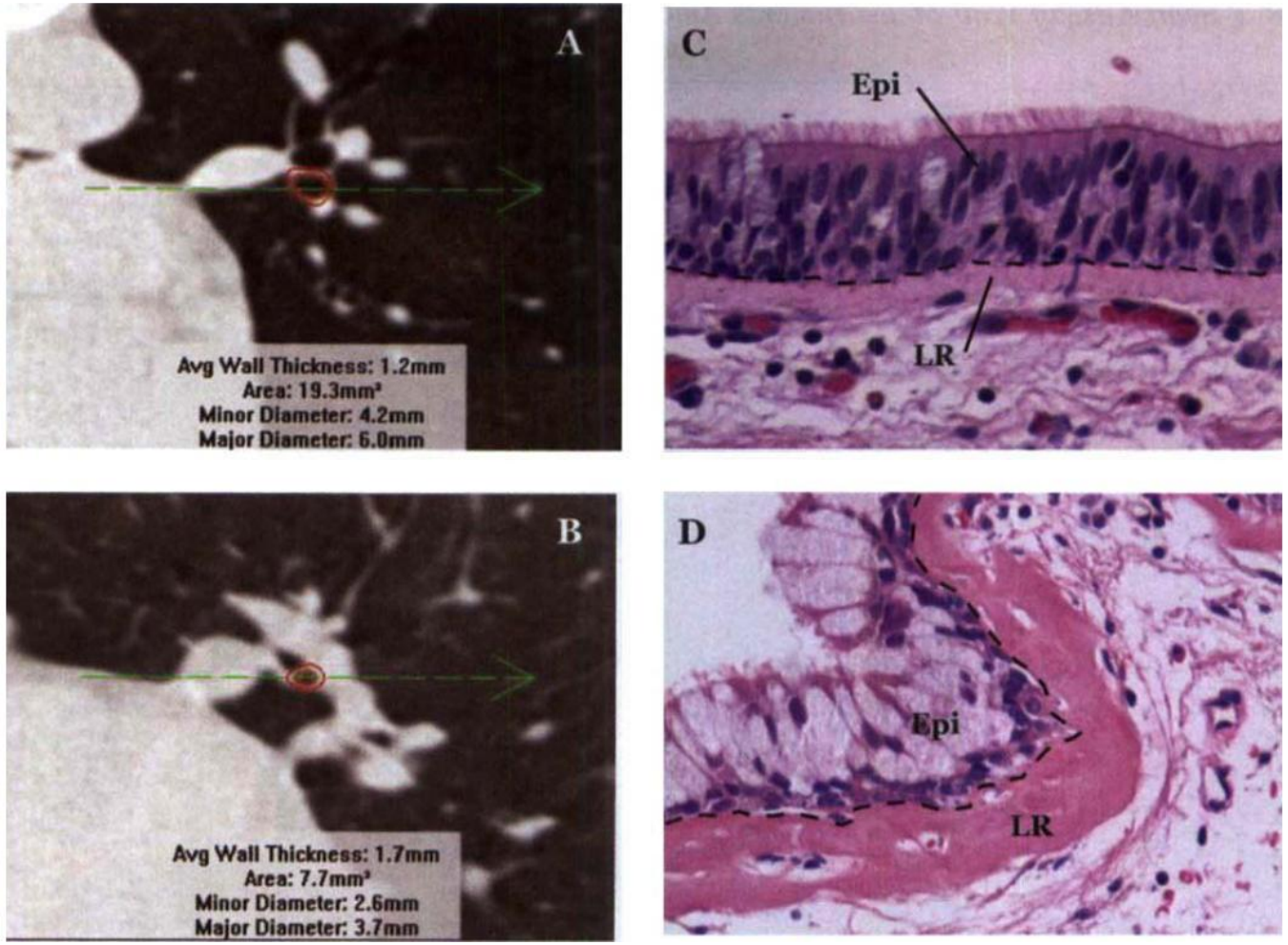
Image Can Enable Phenotyping



	Imaging characteristics	Clinical characteristics
Cluster 1	• Normal airway structure • Increased lung deformation (Jacobian and ADI↑)	• Younger, early onset • Nonsevere asthma • Reversible lung function • Easy to control asthma symptoms
Cluster 2	• Airway luminal narrowing (D_h*↓) • No airway wall thickening (WT*) • Significant reduction of lung deformation (Jacobian and ADI↓)	• Nonsevere and severe asthma • Persistently altered lung function • Marginal to no inflammation • Difficult to control asthma symptoms
Cluster 3	• Airway wall thickening (WT*↑) • No airway luminal narrowing (D_h*) • Moderate reduction of lung deformation (Jacobian and ADI↓)	• Obese, female-dominant • Severe asthma • Reversible lung function • Blood lymphopenia • Difficult to control asthma symptoms
Cluster 4	• Airway luminal narrowing (D_h*↓) • Significant reduction of lung deformation (Jacobian and ADI↓) • Significant air-trapping (AirT%↑)	• Older, late onset, male-dominant • Severe asthma • Persistently altered lung function • Neutrophilic-dominant inflammation • Difficult to control asthma symptoms

Haghighi et al. Respiratory Research 2019; Choi et al. JACI 2017

CT Airway Wall Measurement Reflects Histological Change



Aysola et al. Chest 2008

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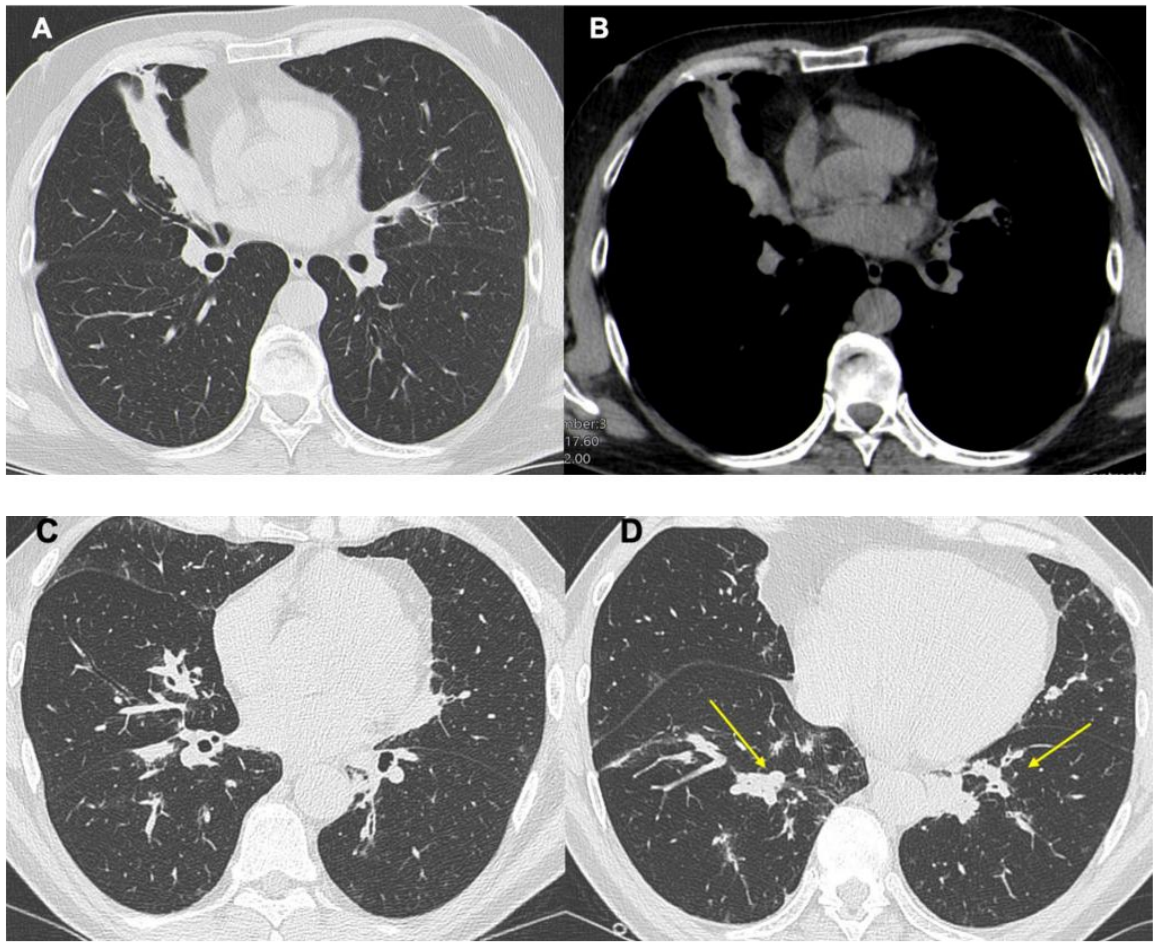
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Traditional approach

CXR abnormality

Other disease spectrum

ABPA, EGPA, etc.

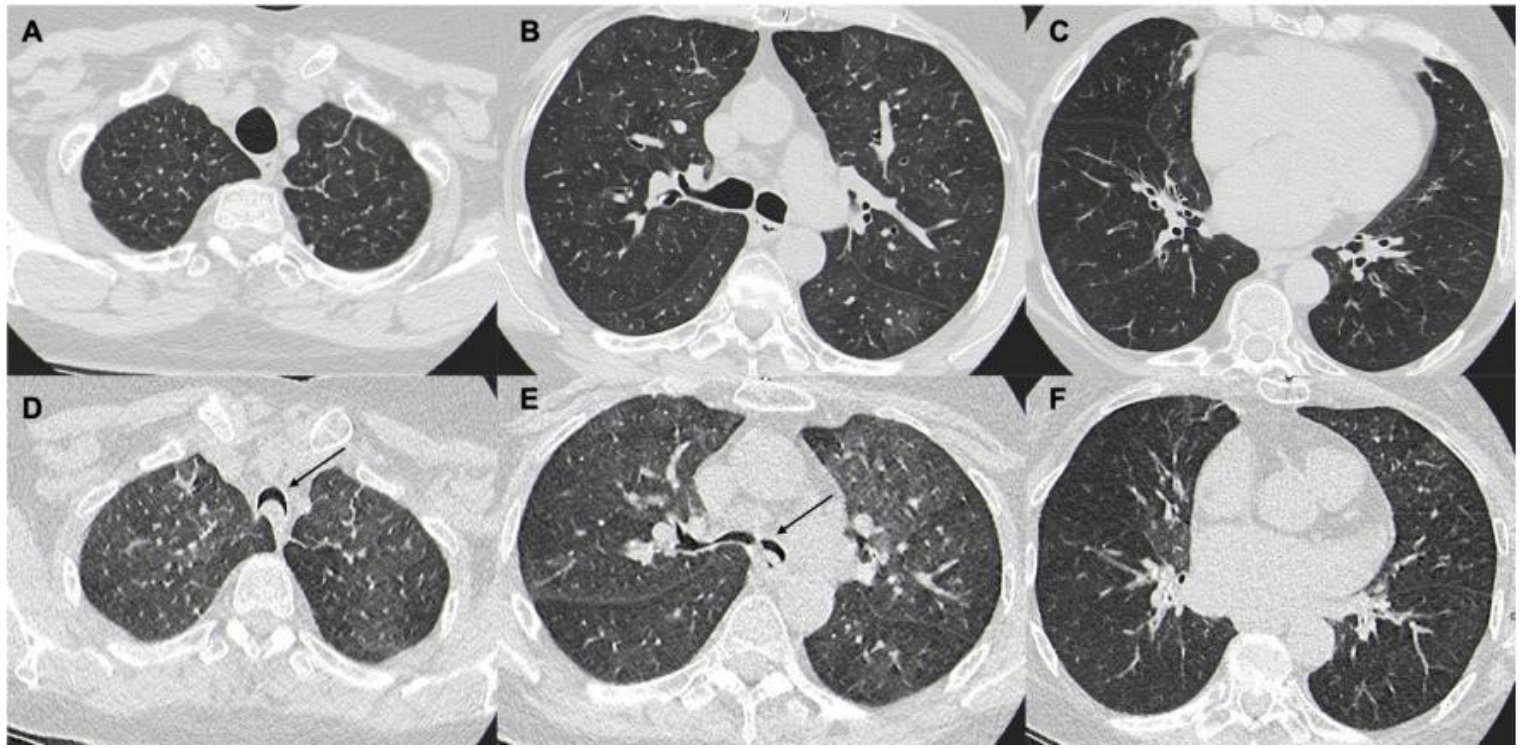


Cozzi et al. La radiologia medica 2026

Beyond the traditional approach

Asthma-related findings

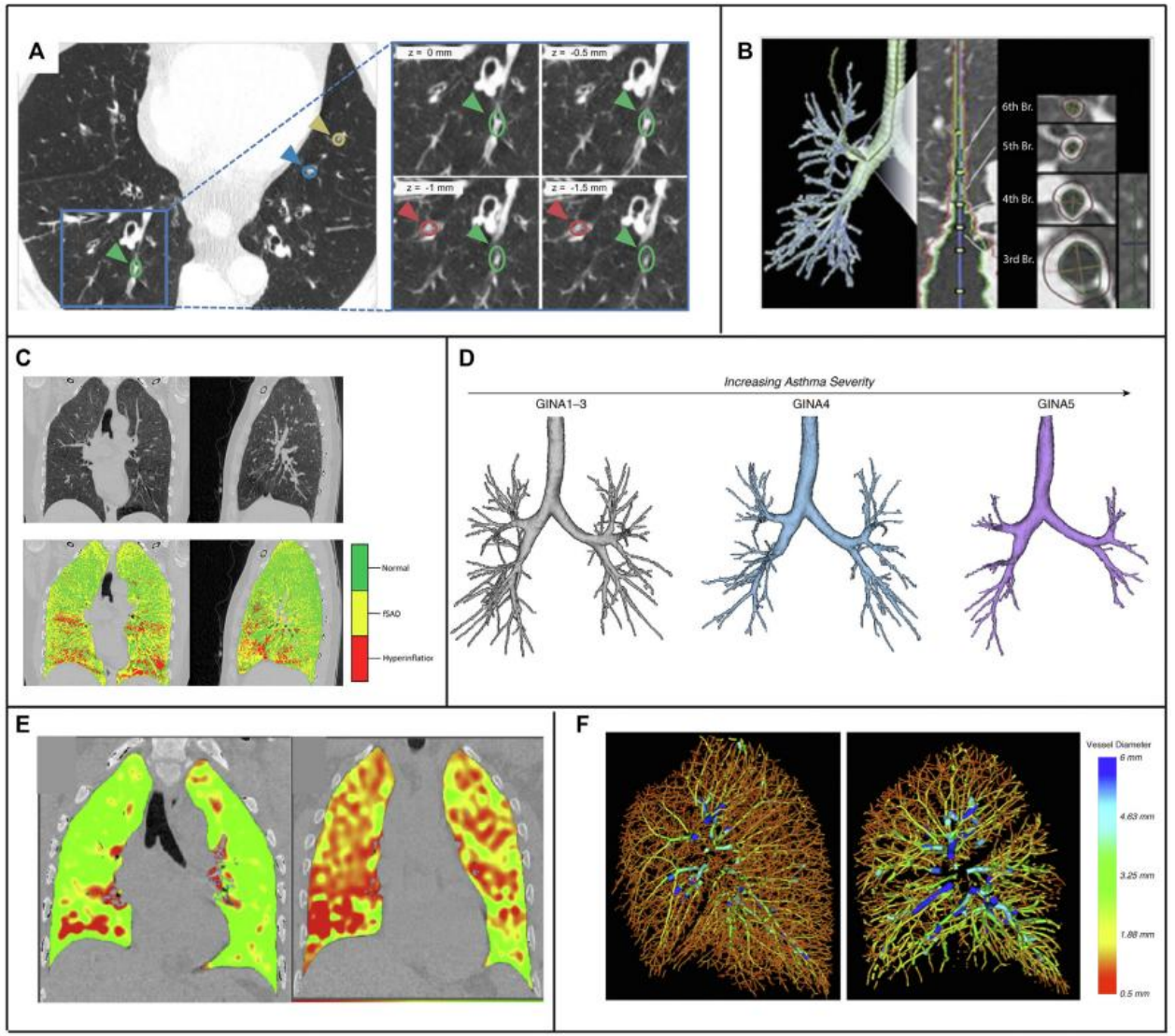
- Bronchial wall thickening
- Airway collapse
- Air trapping



Cozzi et al. La radiologia medica 2026

What does quantitative CT show?

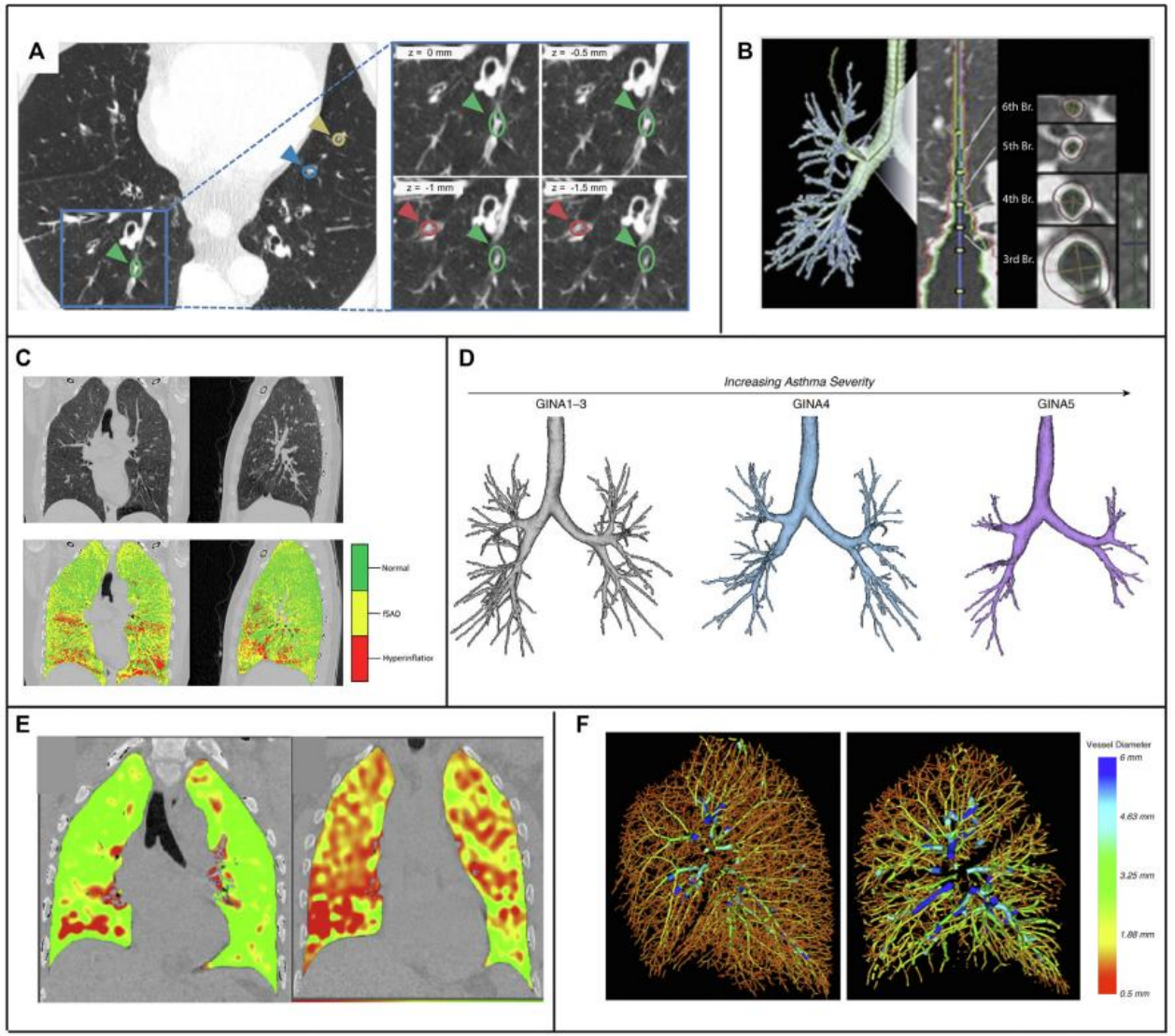
- Mucus plug
- Bronchial wall thickness
- PRMfSAD
- Total airway count
- Jacobian determinant
- Vascular pruning



Matheson et al. 2025 JACI

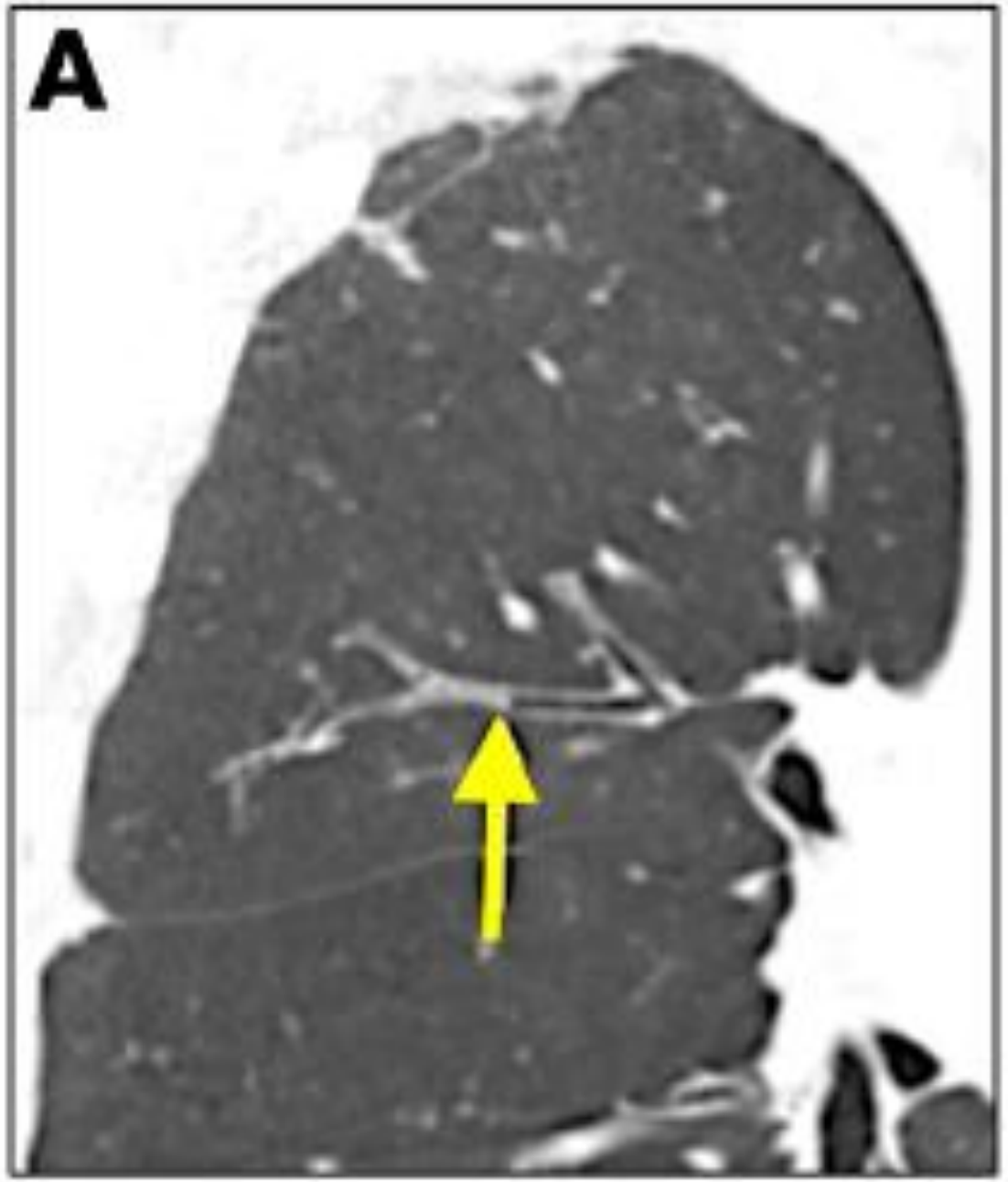
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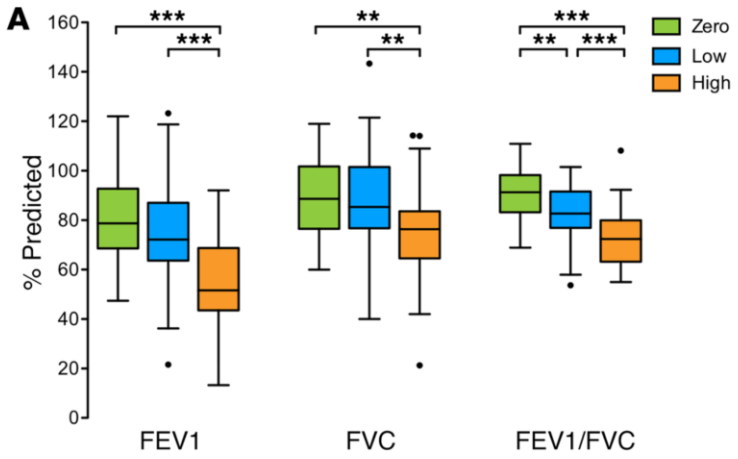
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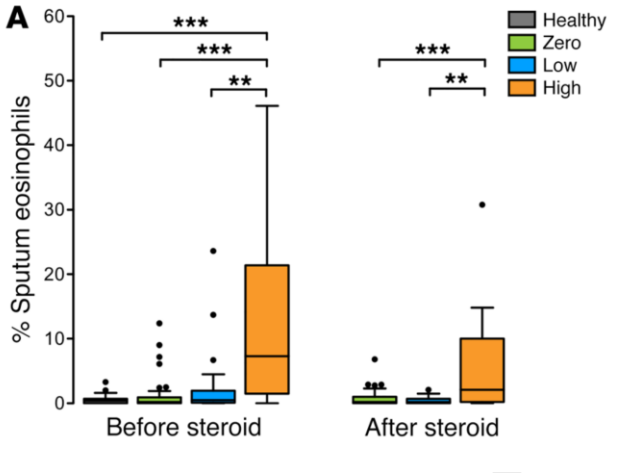


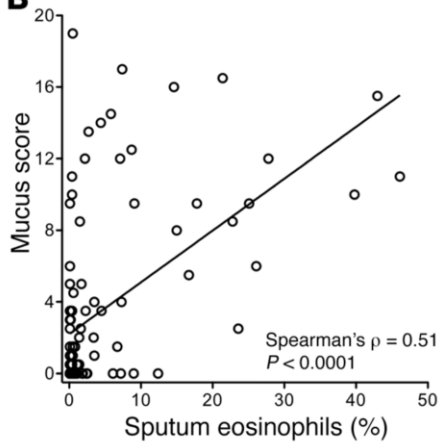
Matheson et al. 2025 JACI

ıent of MPS



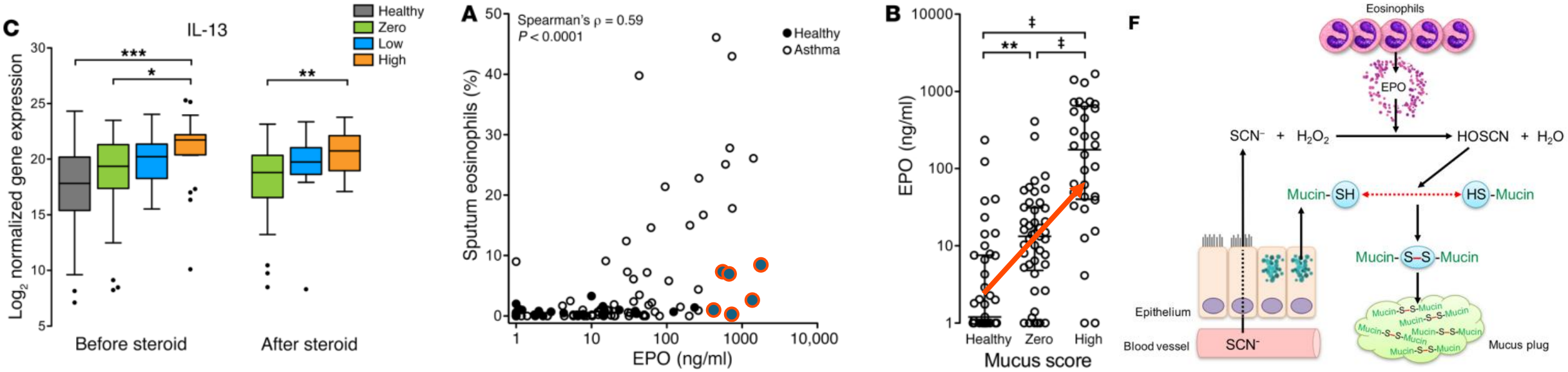






Dunican et al. JCI 2018

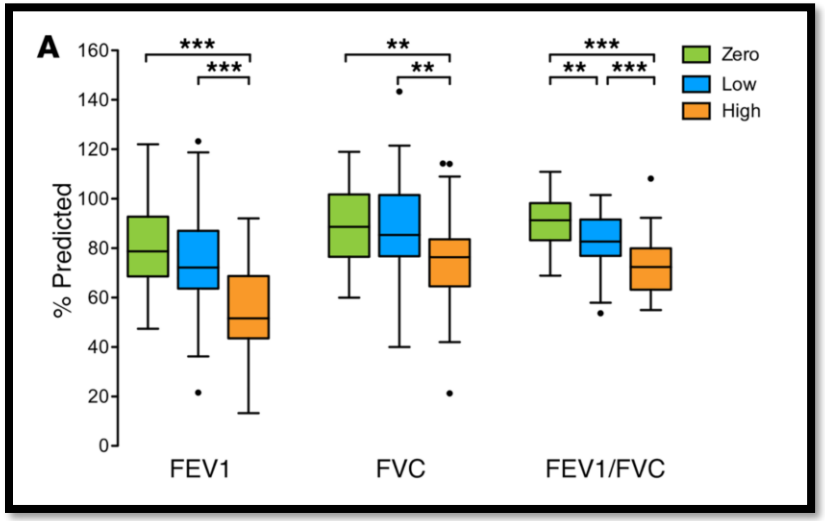
Eosinophil products and mucus plugging



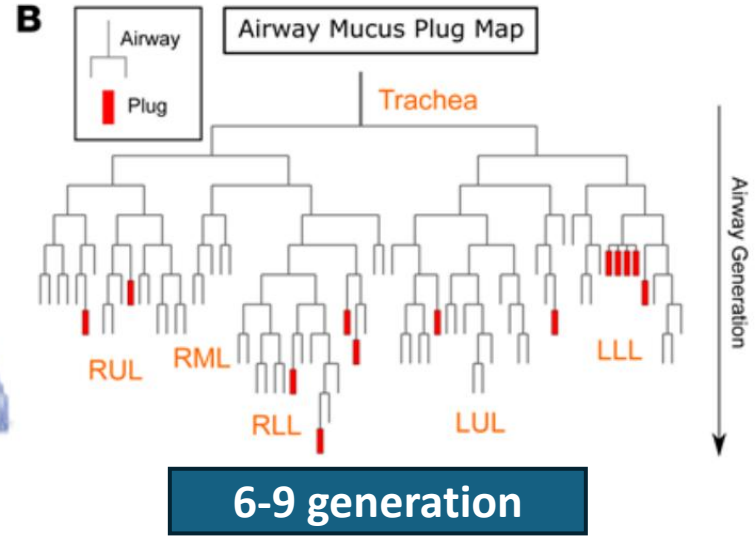
IL-13 increases thiocyanate transfer into airway lumen
HOSCN was generated by EPO
HOSCN target mucin polymer to generate mucin crosslink

Dunican et al. JCI 2018

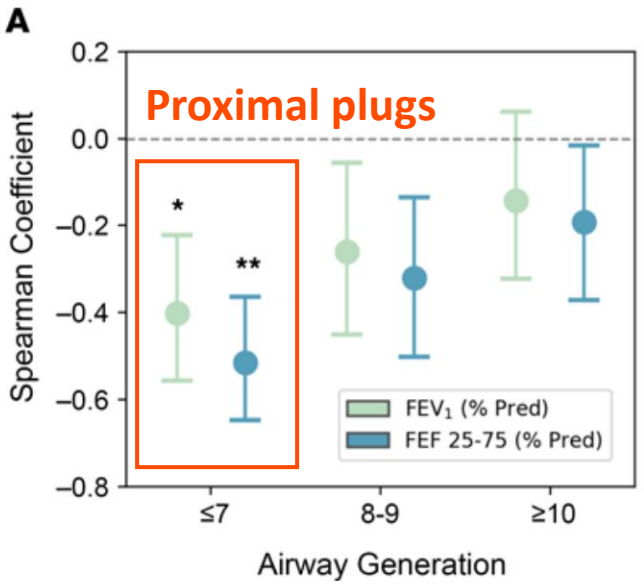
Proximal Plugs Affected Lung Function

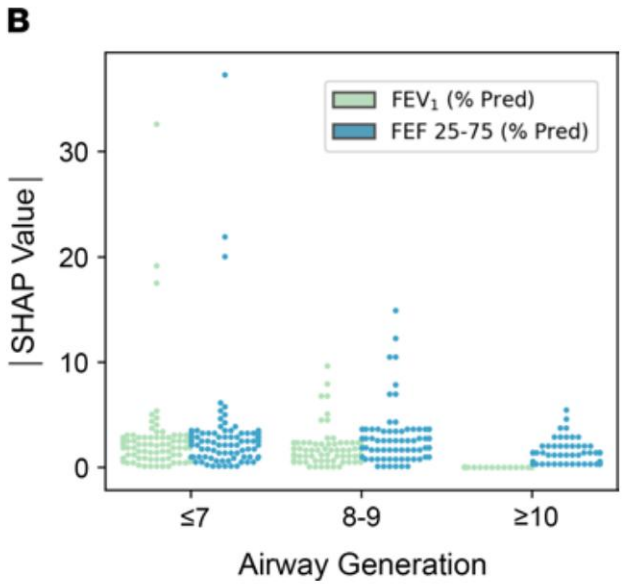


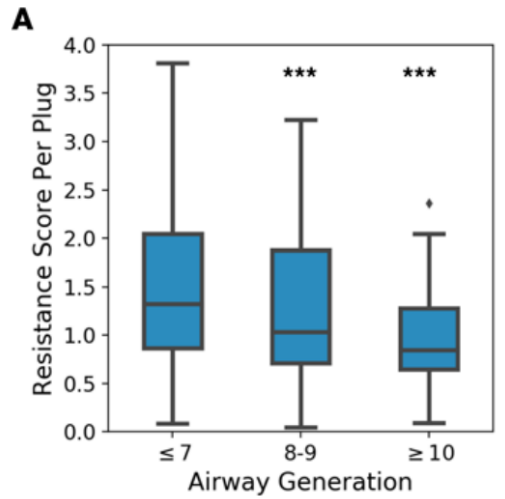


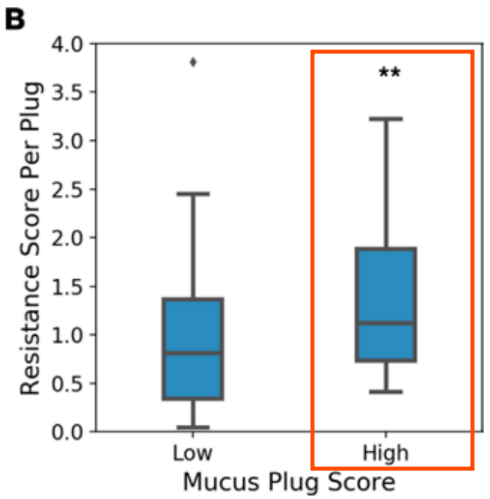


6-9 generation



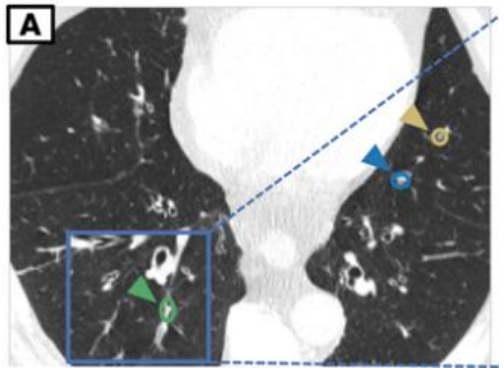


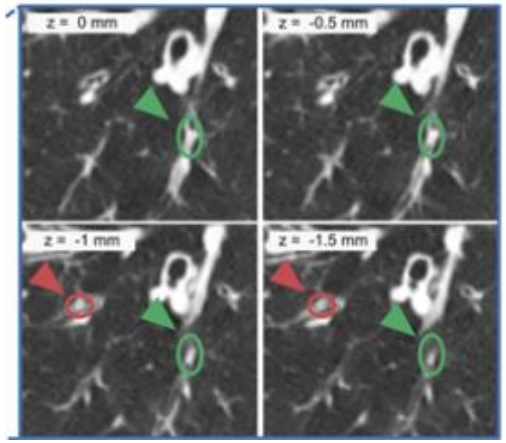


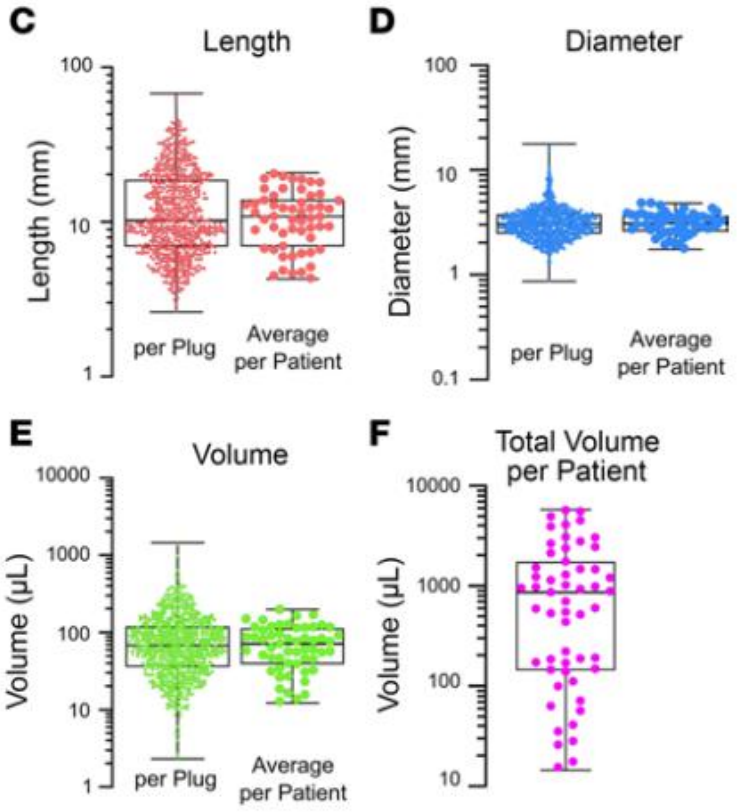


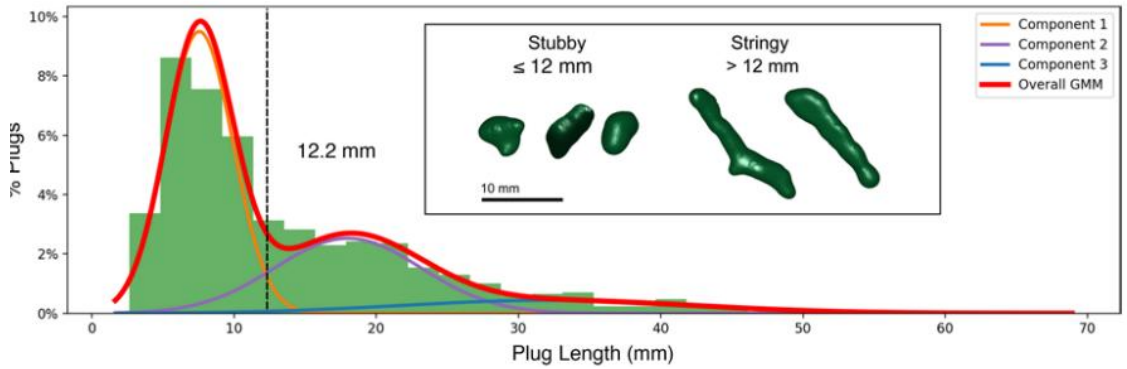
Huang et al. JCI Insight 2024

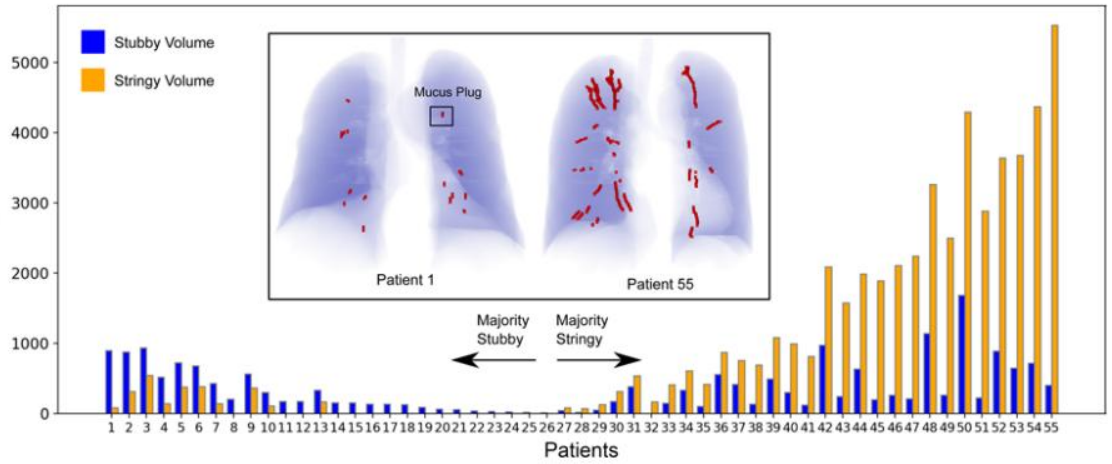
Mucus Plug Phenotyping







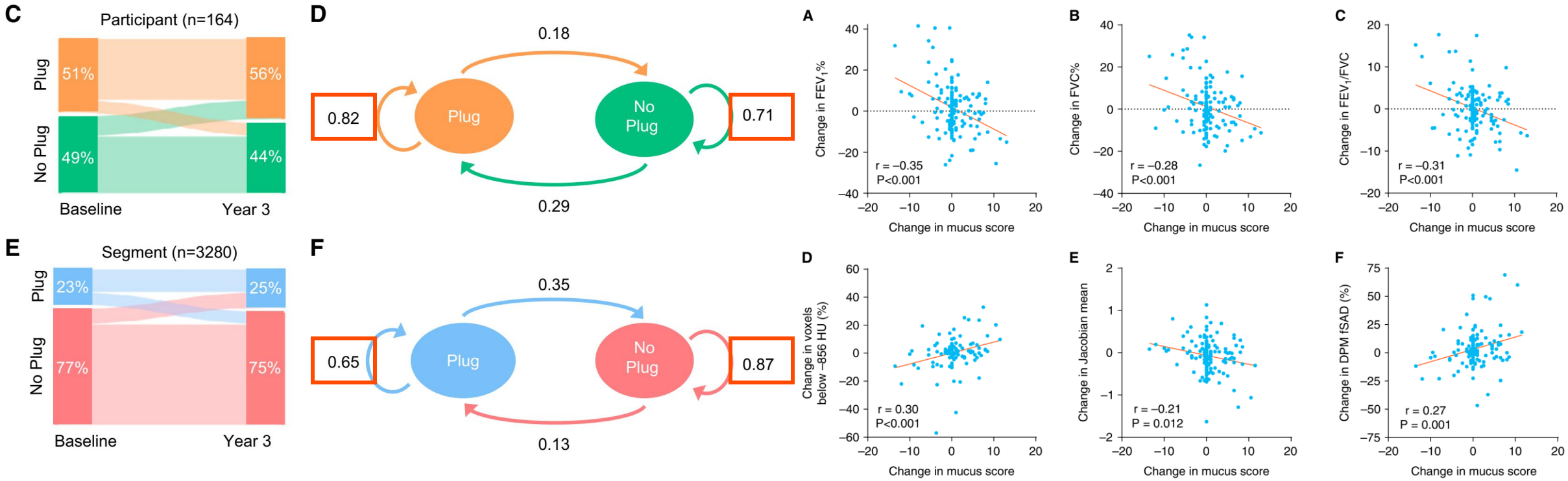




① 사람이 plug 위치를 지정
② GK clustering으로 plug를 segmentation
③ 형태와 밀도를 정량화

Huang et al. JCI Insight 2024

Longitudinal changes in MPS, lung function, imaging markers



Mucus plugs: persistent asthma phenotype
Changes in mucus plugs: associated with change in airflow over time

Tang et al. AJRCCM 2022

Mucus plug and MRI ventilation defect

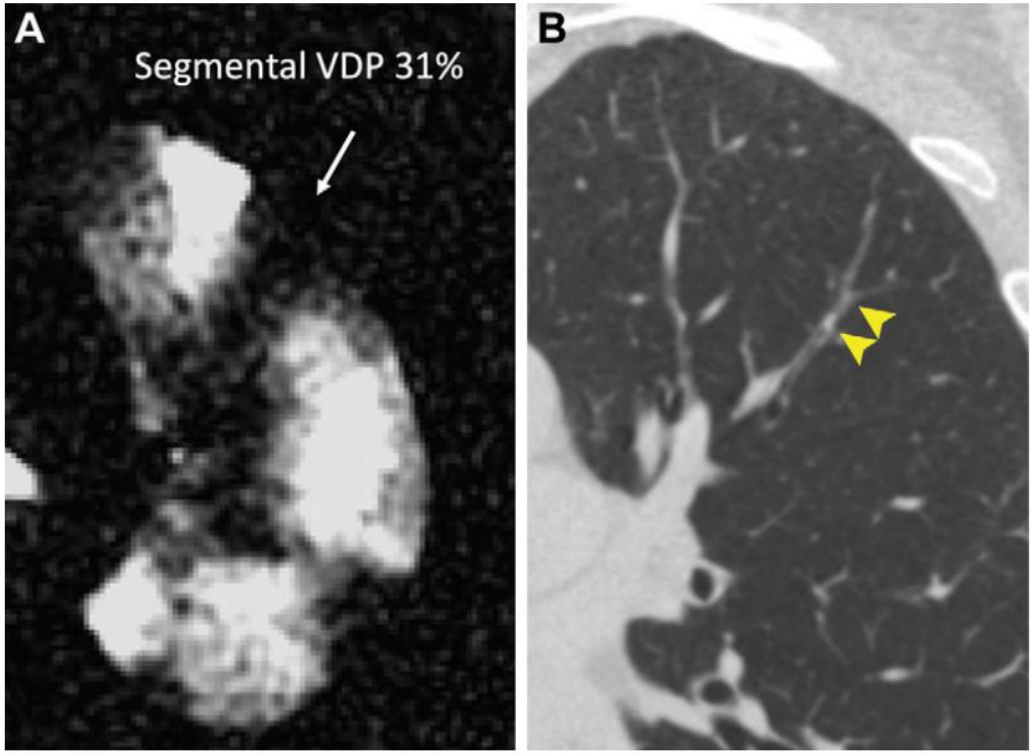
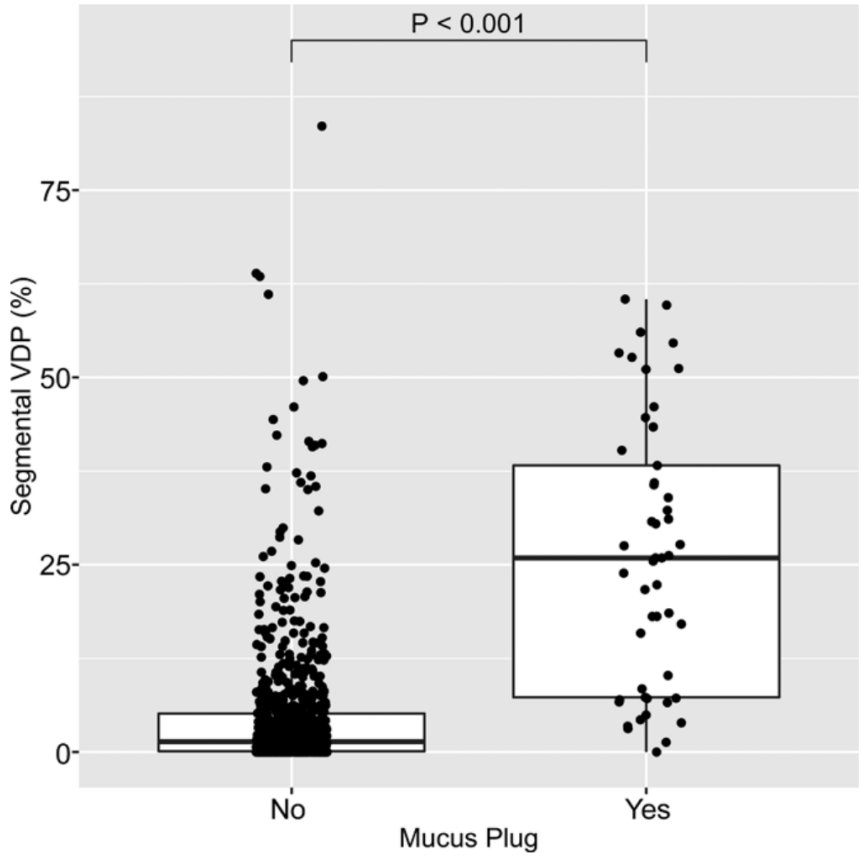


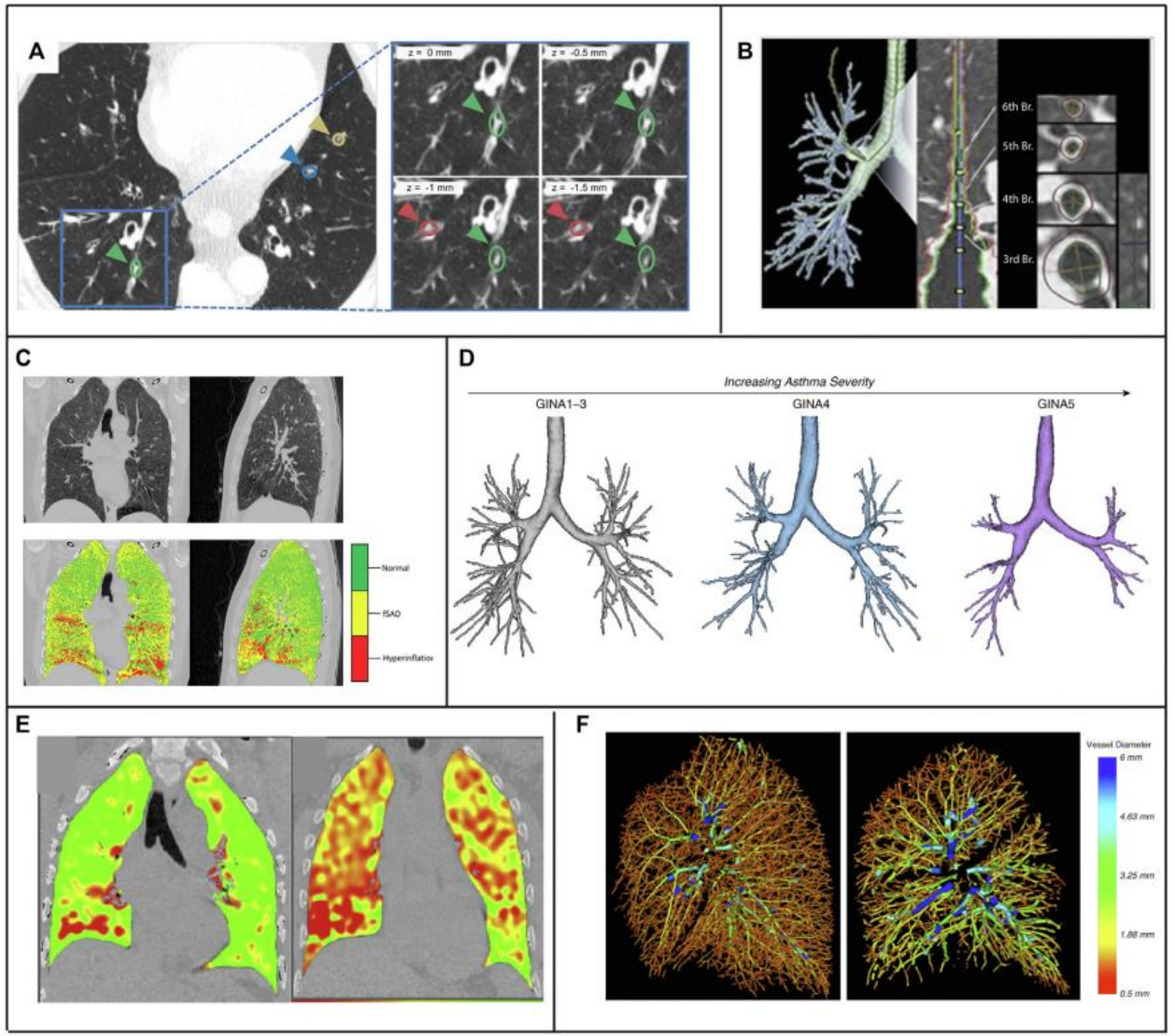
Figure 2: Representative images of **(A)** segmental ventilation defect percentage (VDP) affecting 31% of the segmental lobe volume at hyperpolarized helium 3 MRI (arrow) and **(B)** a spatially overlapping mucus plug visualized at CT (arrowheads).



Mummy et al. Radiology 2022

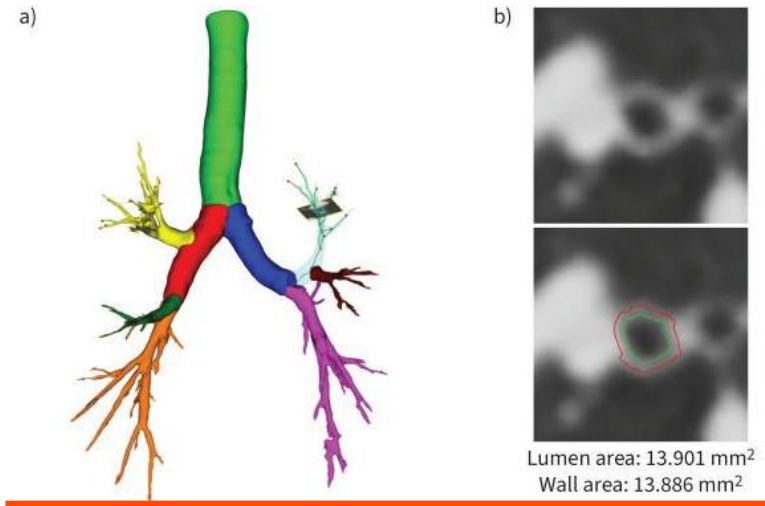
What does quantitative CT show?

- Mucus plug
- **Bronchial wall thickness**
- PRMfSAD
- Total airway count
- Jacobian determinant
- Vascular pruning



Matheson et al. 2025 JACI

Airway indices



Wall thickness (WT)

$$WT = \frac{D_{outer} - D_{inner}}{2}$$

WT adjusted for airway size (WT%)

$$WT\% = \frac{WT}{D_{outer}} \times 100$$

Wall area (WA)

Wall Area Percentage (WA%)

WA/(WA+LA) x 100

$$WA\% = \frac{13.886}{13.886 + 13.901} \times 100 \approx 50\%$$

Pi10, Pi slope

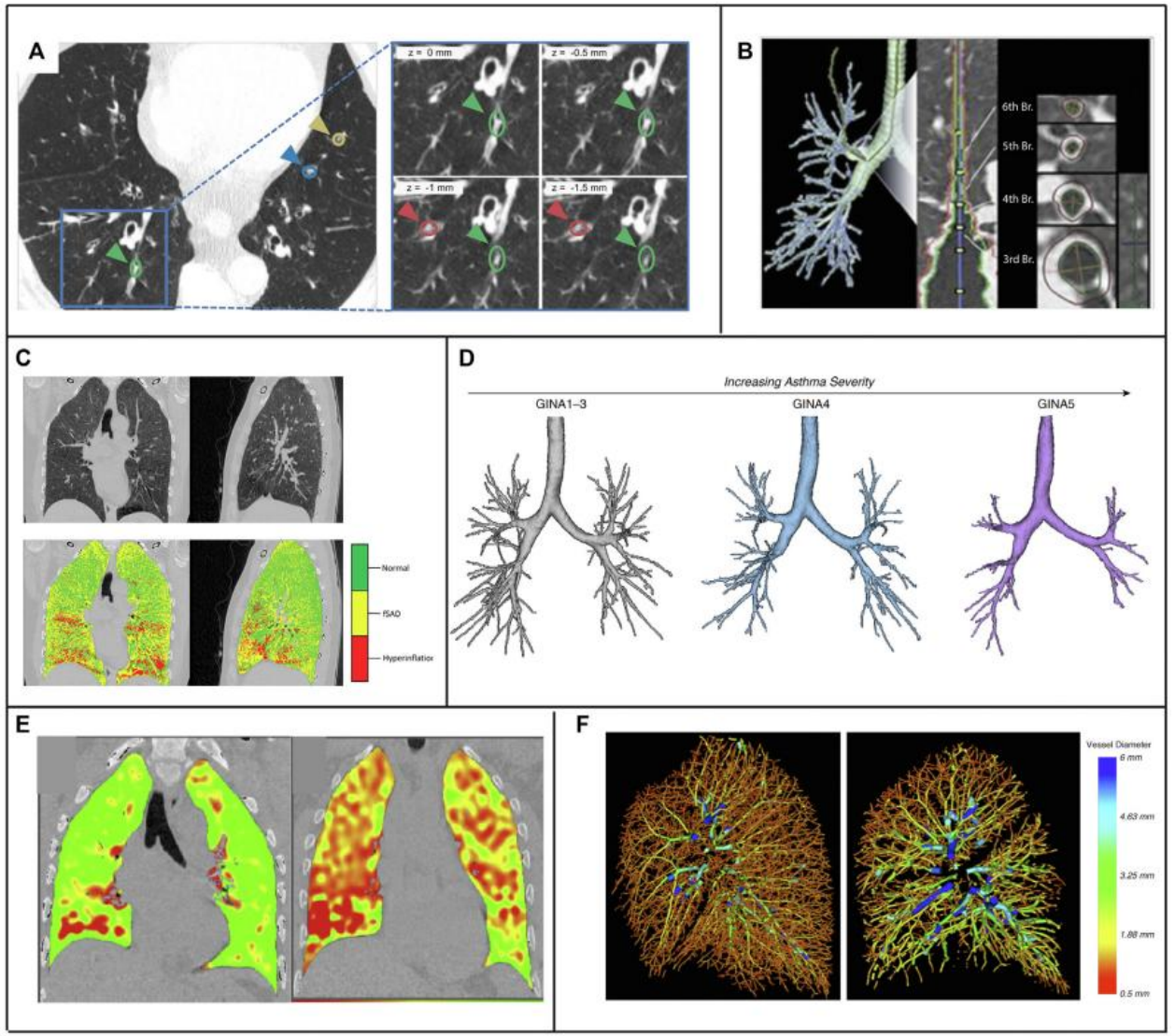
$$\sqrt{WA} = \beta_0 + \beta_1 \times Pi$$

$$Pi10 = \beta_0 + \beta_1 \times 10$$

Smoorenburg et al. ERJ Open 2025

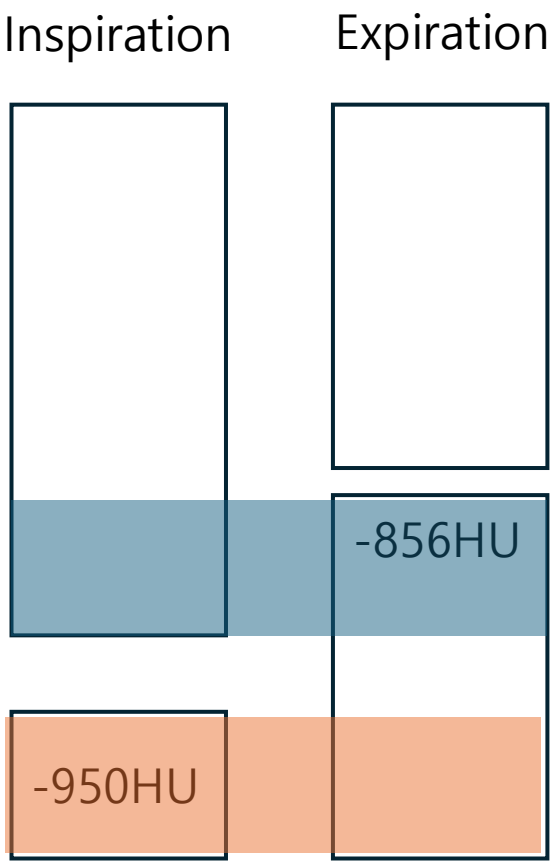
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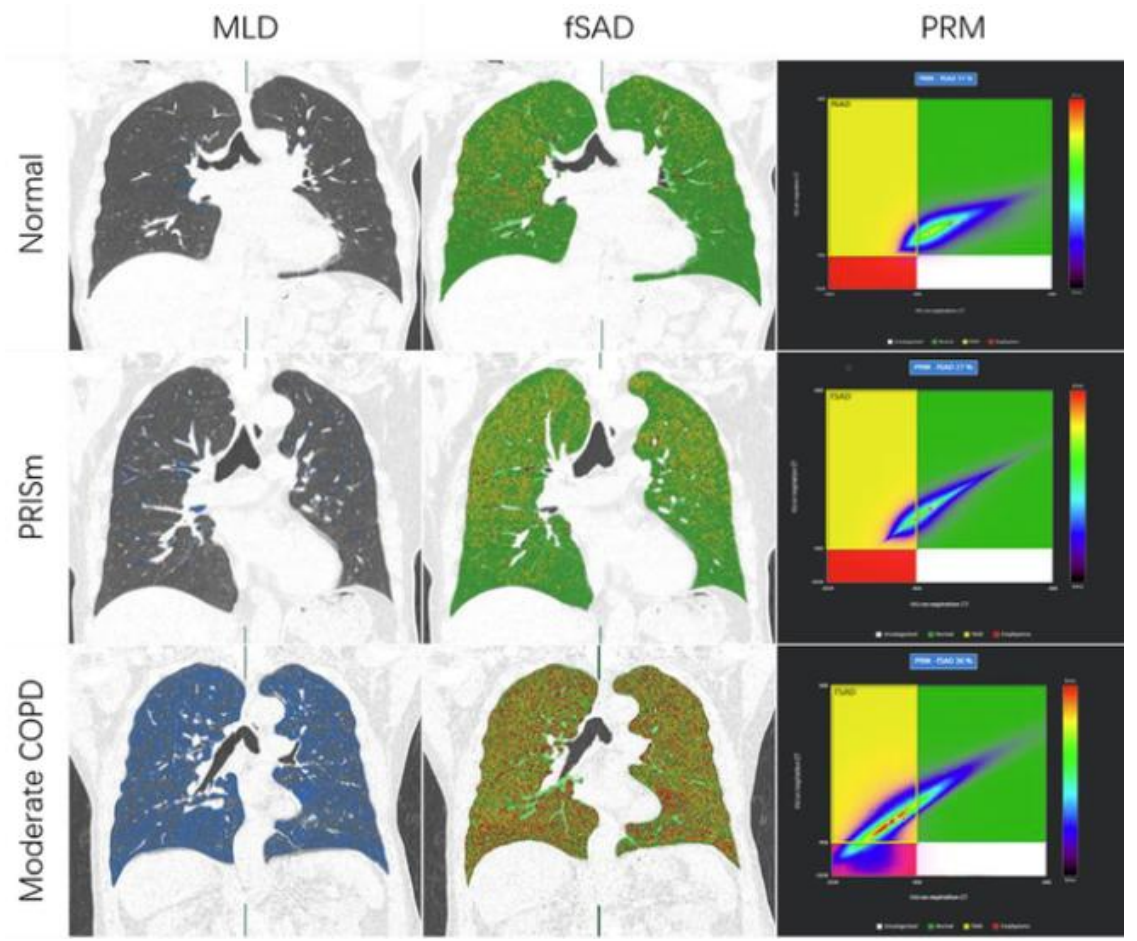
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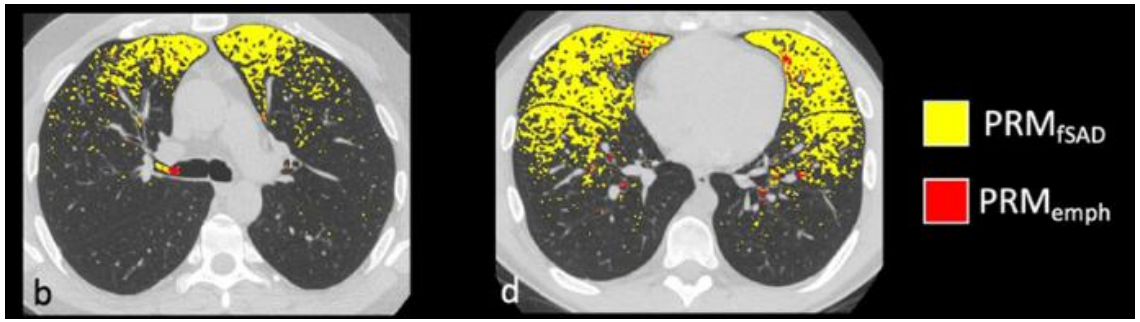


Matheson et al. 2025 JACI

PRMfSAD







Carey et al. Frontier physiology 2023

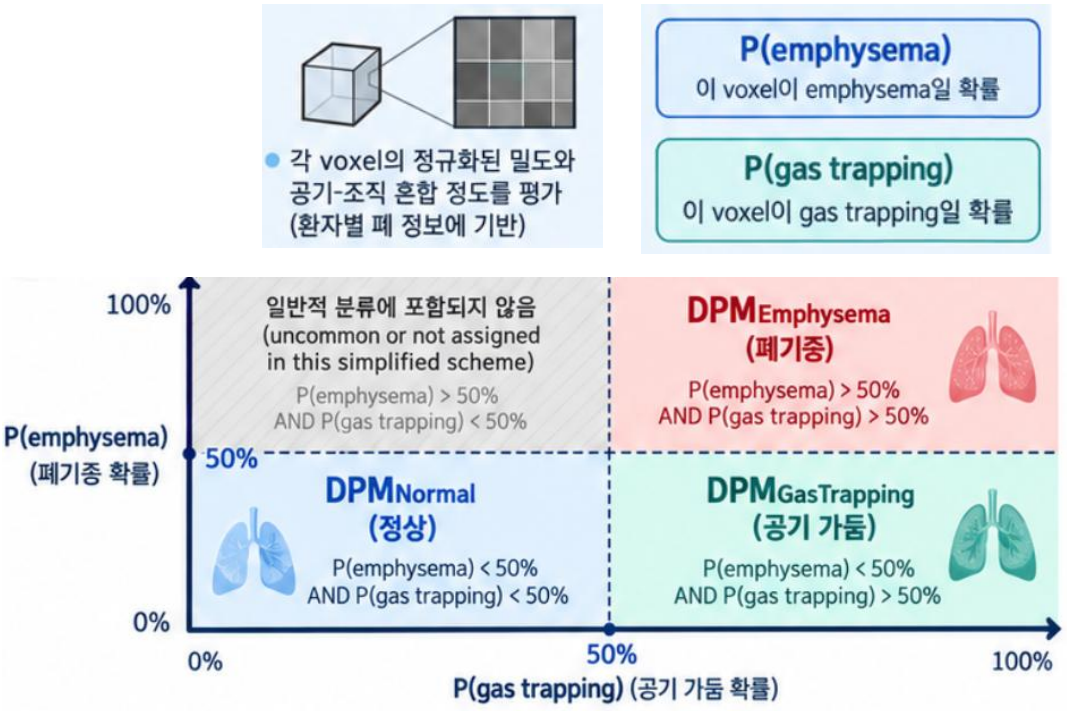
DPM

Imaging Small Airway Disease: Probabilities and Possibilities

Surya P. Bhatt, M.D.

University of Alabama at Birmingham Lung Imaging Core, University of Alabama at Birmingham Lung Health Center, and Division of Pulmonary, Allergy and Critical Care Medicine, University of Alabama at Birmingham, Birmingham, Alabama

ORCID ID: 0000-0002-8418-4497 (S.P.B.).

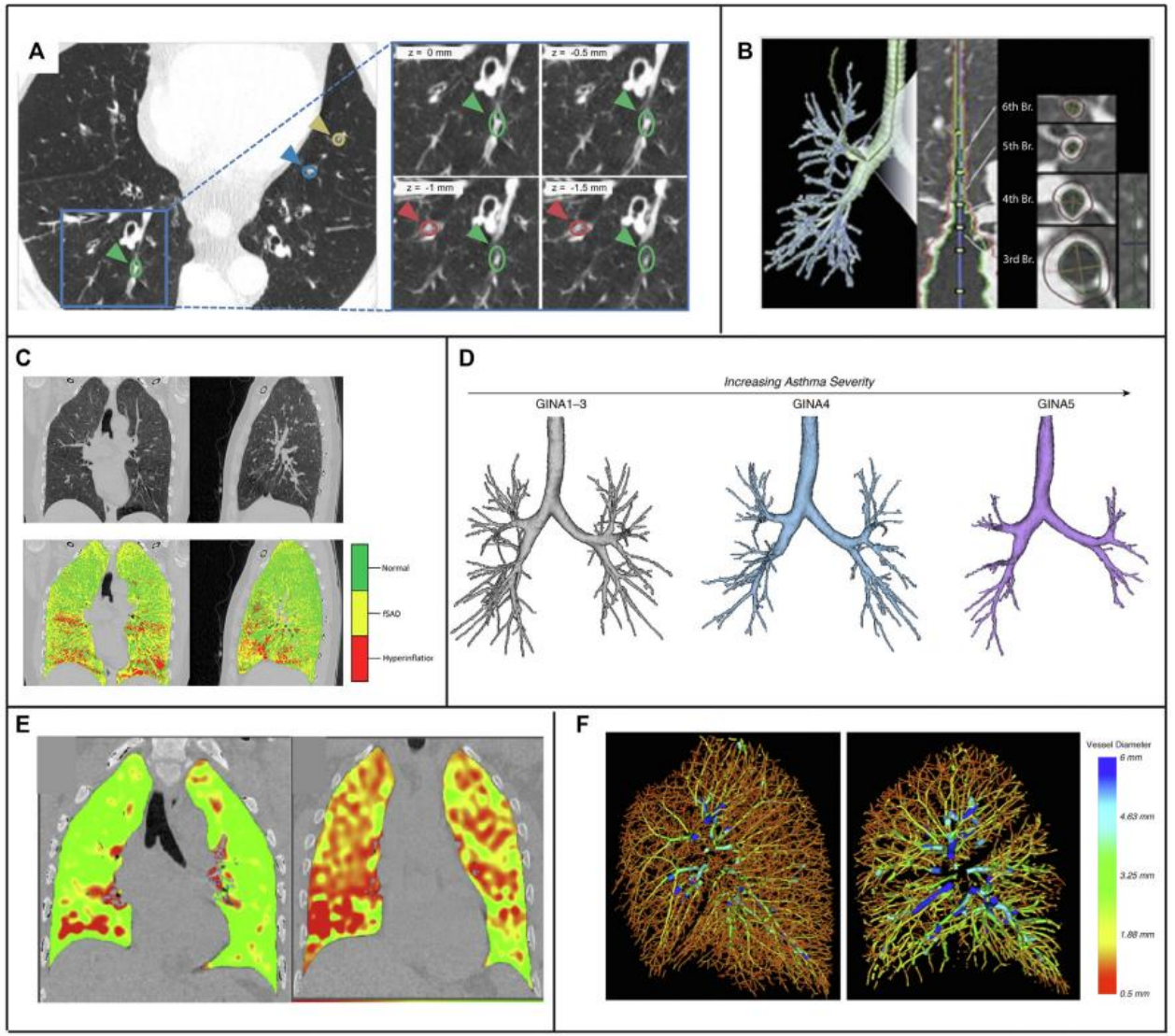


The Disease Probability Measure (DPM) is another novel application of image matching designed to overcome the limitations of threshold-based pairing by assigning labels to voxel pairs based on the probability of emphysema and gas trapping. These probabilities are first calculated in individual subject-specific lungs based on the normalized densities on inspiration and expiration on a continuous scale. Subsequently, voxels with <50% probability of both emphysema and gas trapping are labeled DPM_{Normal}, voxels with >50% probability of both emphysema and gas trapping are labeled $DPM_{Emphysema}$, and voxels with a discordant probability of <50% for emphysema but >50% for gas trapping are assigned a label of $DPM_{GasTrapping}$. Because these metrics of small airway disease are indirect and surrogate measures, it is important to test whether these really estimate what they purport to measure.

Image was generated by ChatGPT

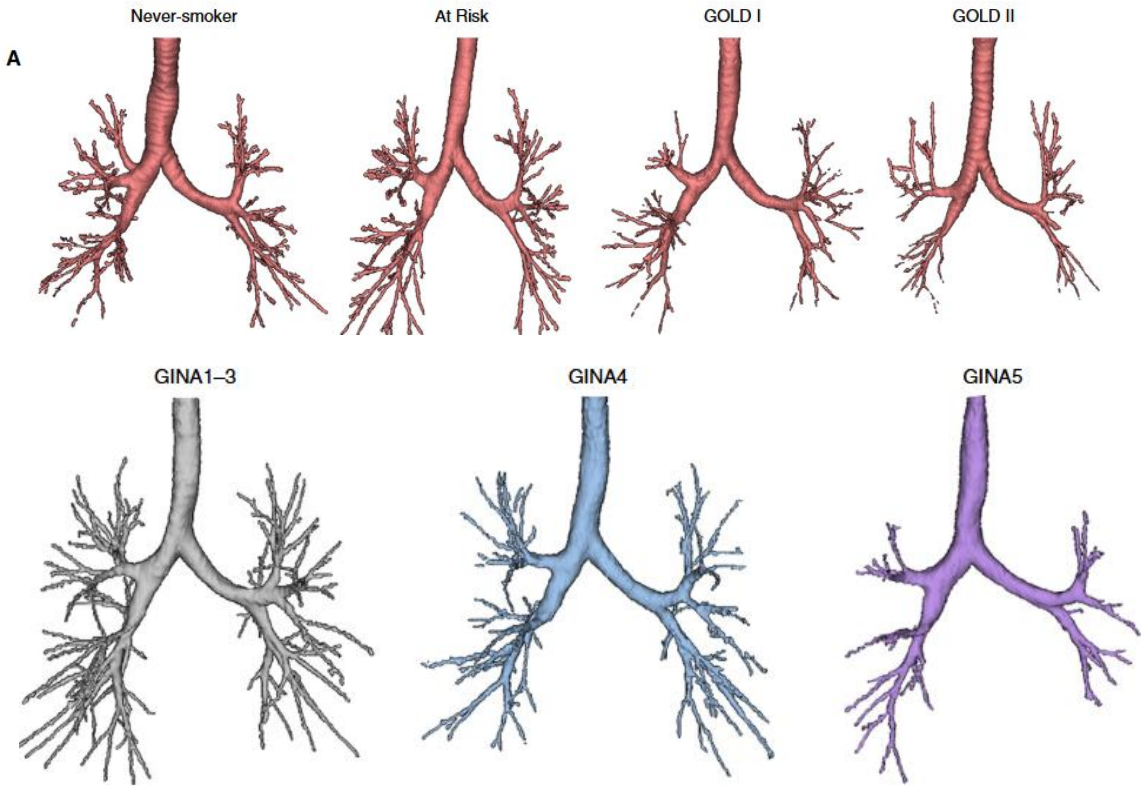
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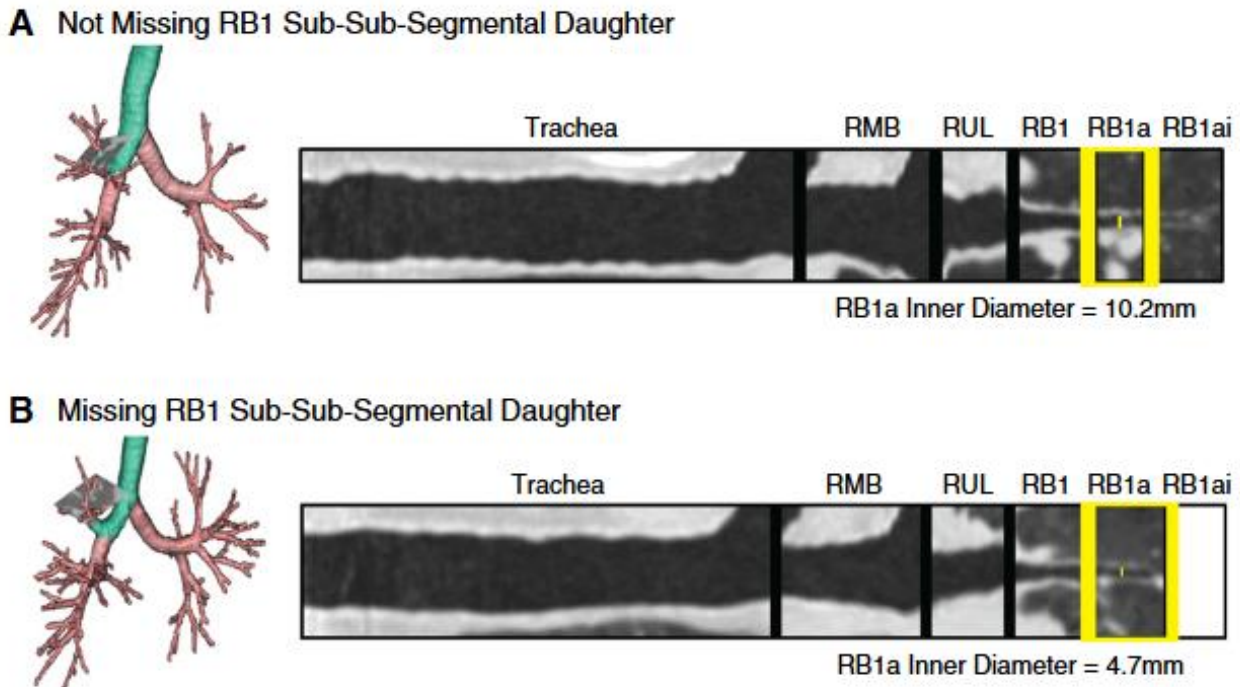
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Total airway count

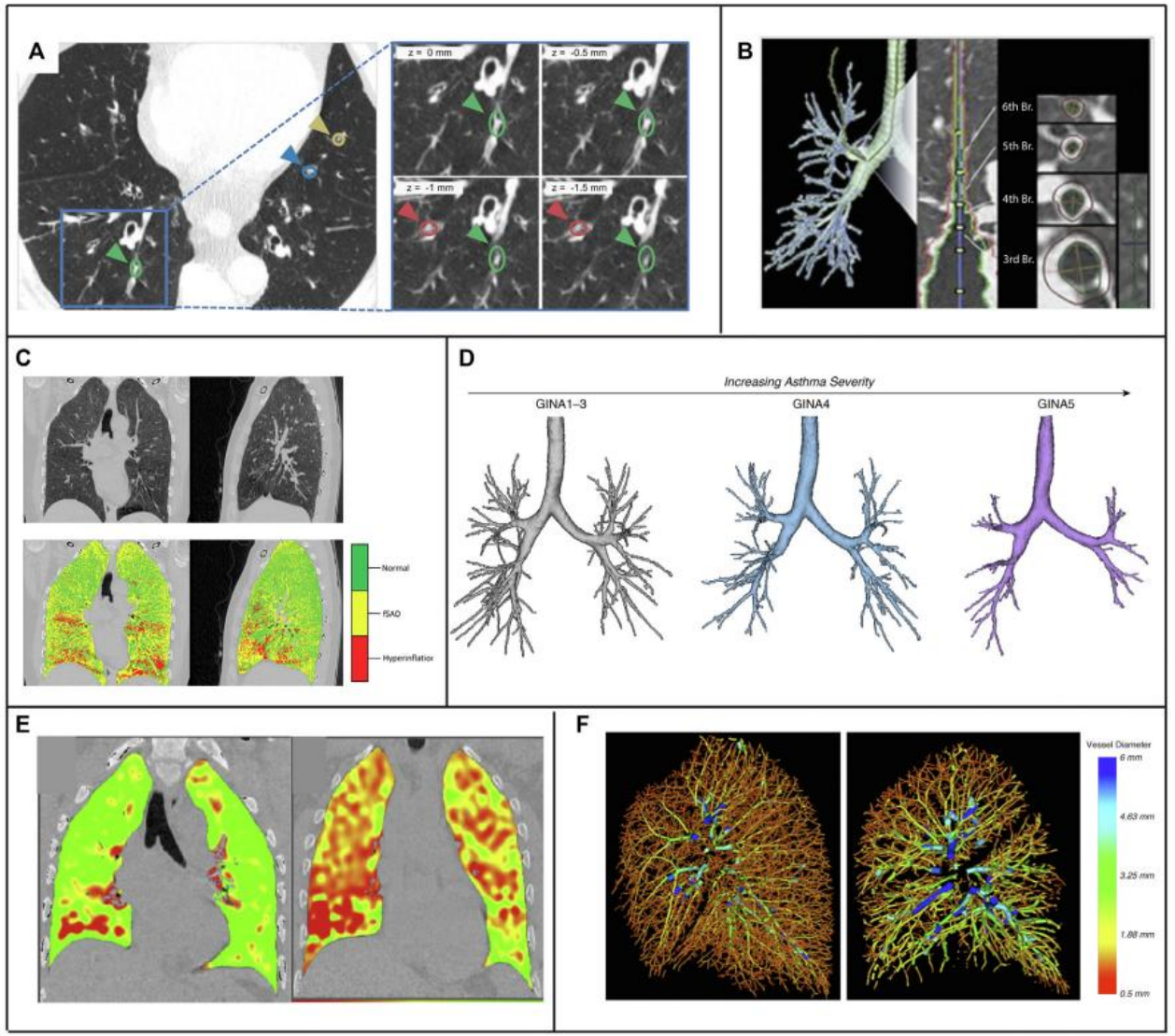




Kirby et al AJRCCM 2018; Eddy et al. AJRCCM 2020

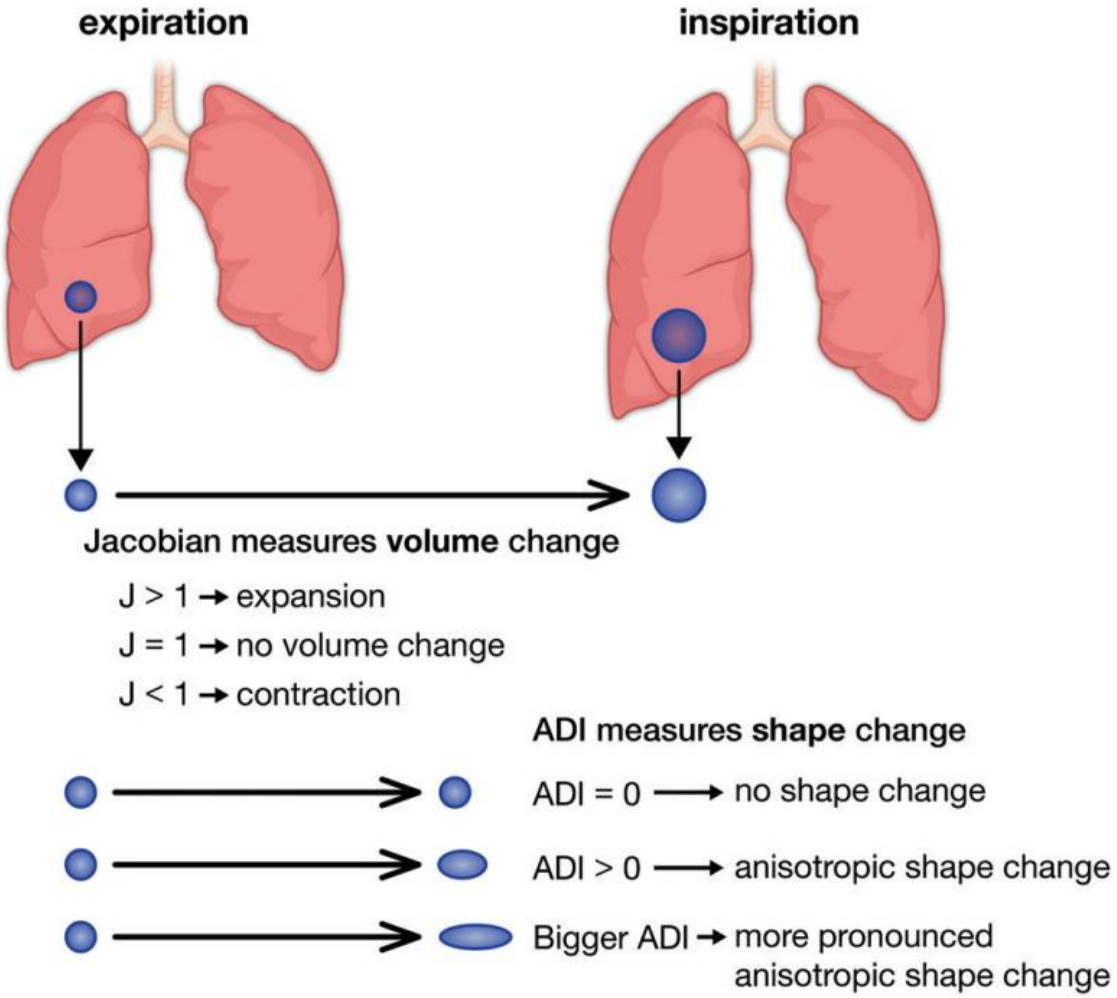
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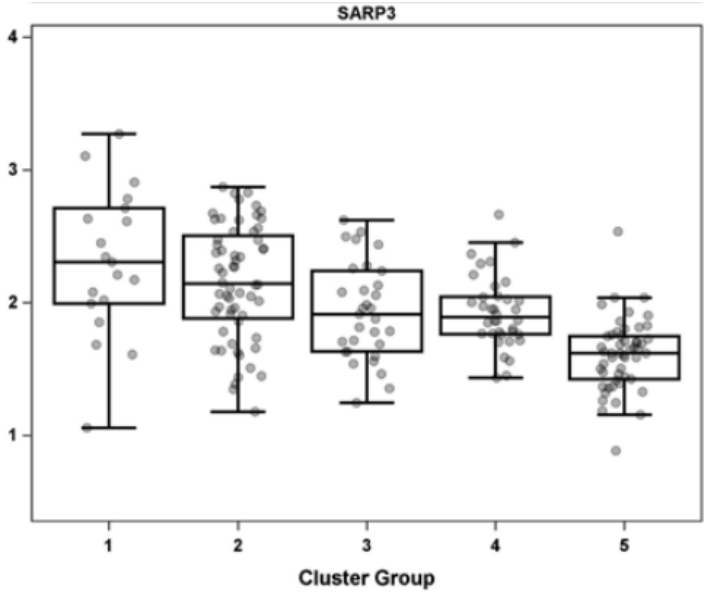


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Visual representation of Jacobian (J) and anisotropic deformation index (ADI)



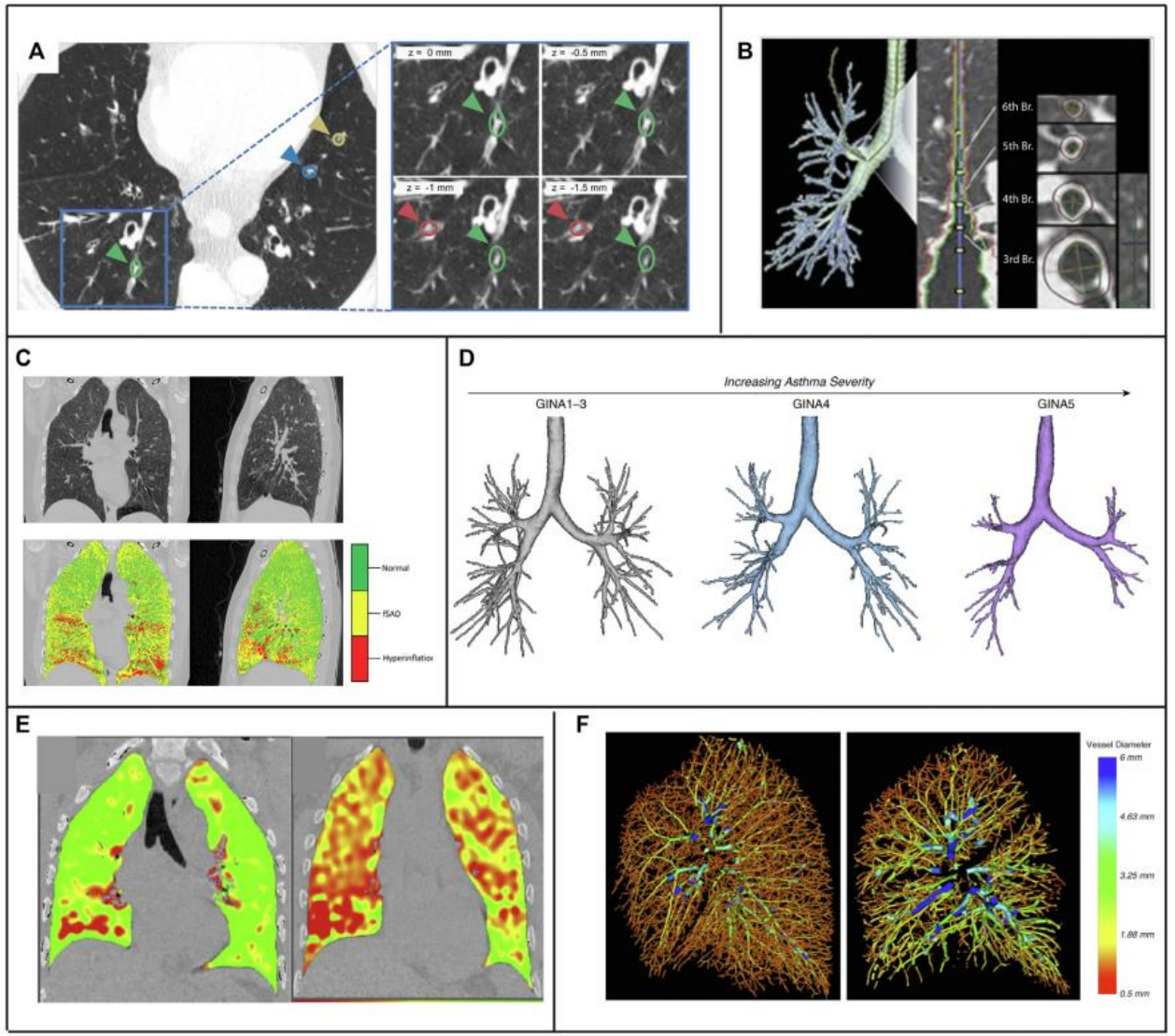
- Cluster 1 (mild reversible, n=26)
- Cluster 2 (mild persistent, n=74)
- Cluster 3 (obese asthma, n=36)
- Cluster 4 (severe reversible, n=41)
- Cluster 5 (severe fixed, n=54)



Trivedi et al. 2022 Radiology

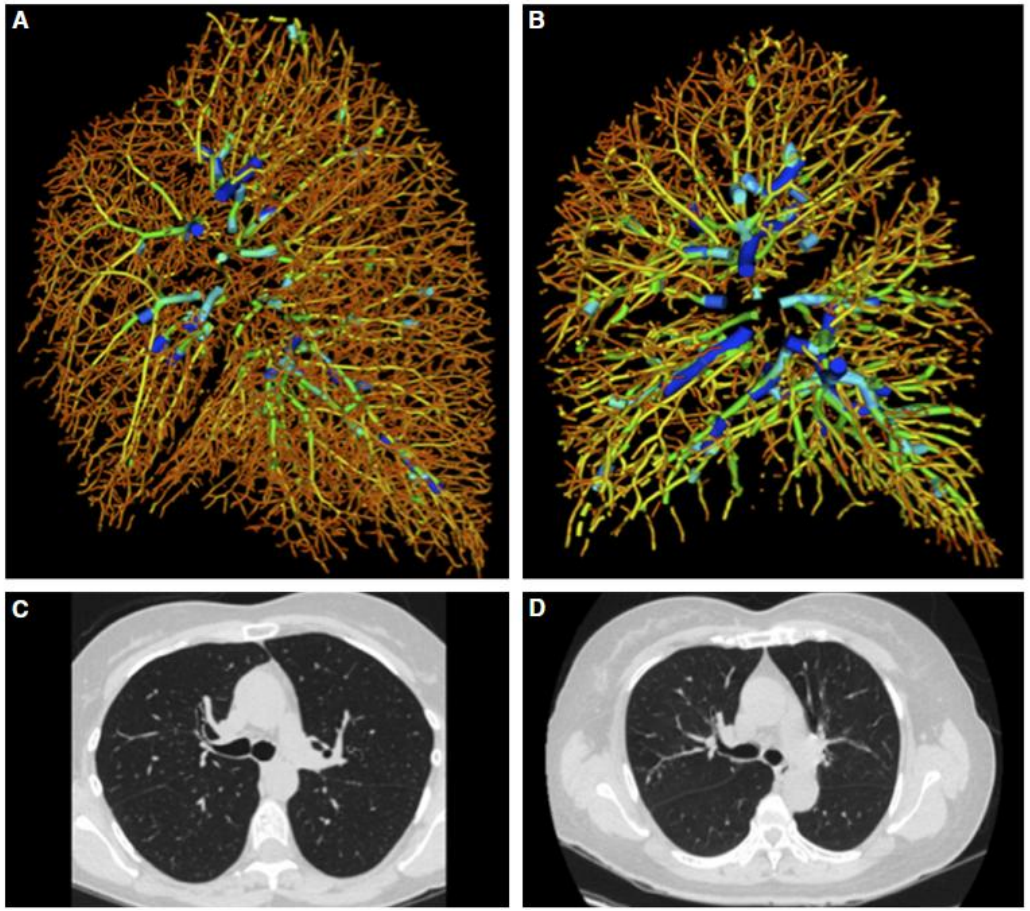
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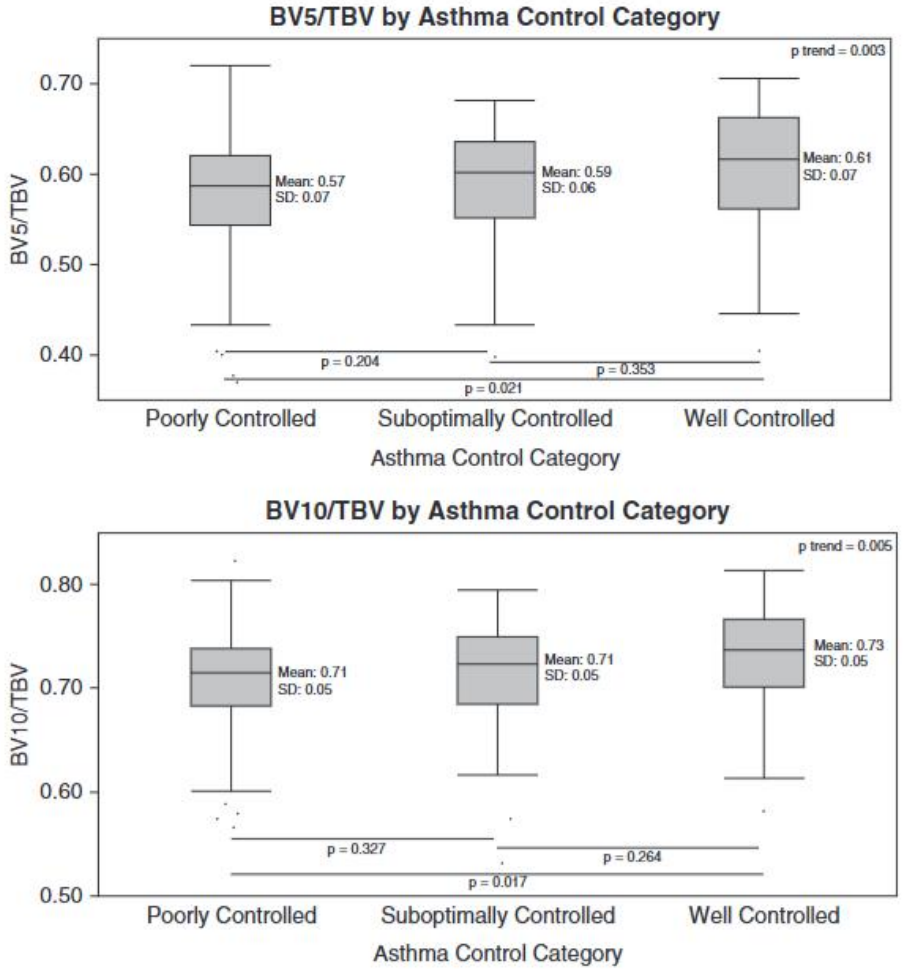
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Matheson et al. 2025 JACI

Vascular pruning



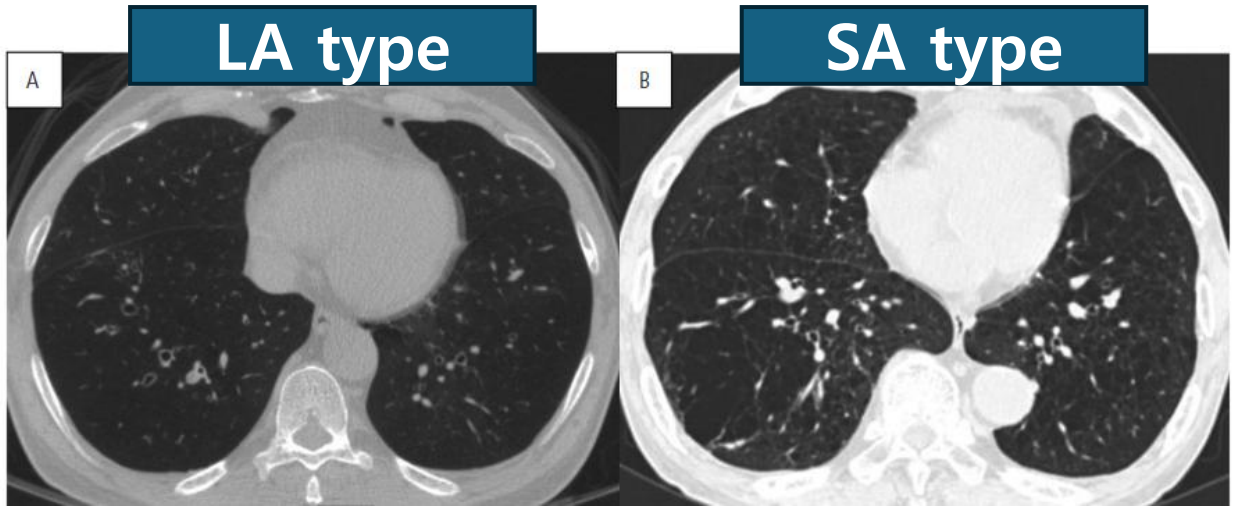


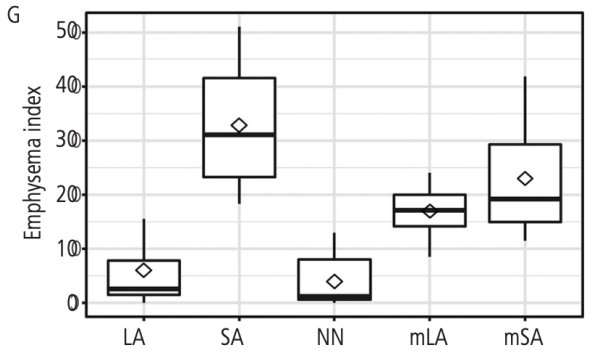
Ash et al. AJRCCM 2018

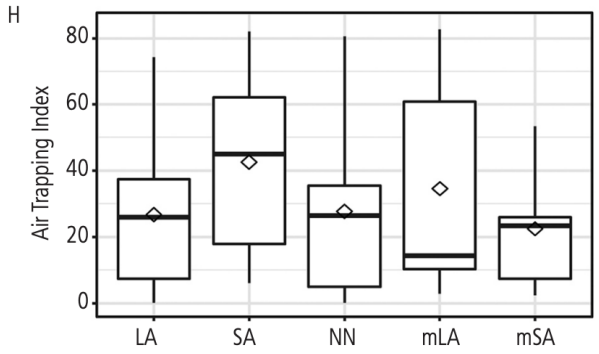
Contents

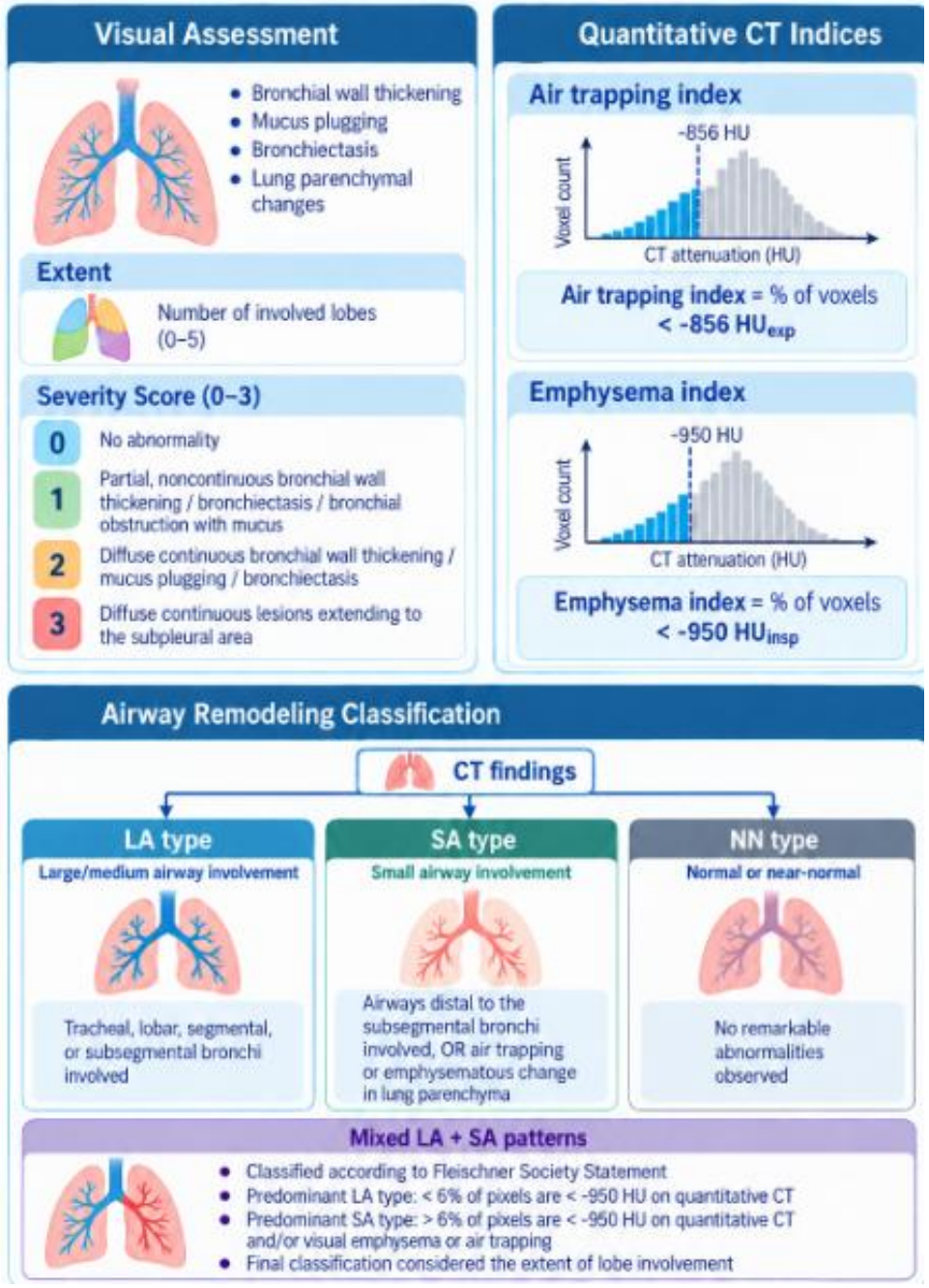
Why CT imaging in Asthma
What can we get from the CT
How to use CT imaging in Clinic

Phenotyping: patient selection



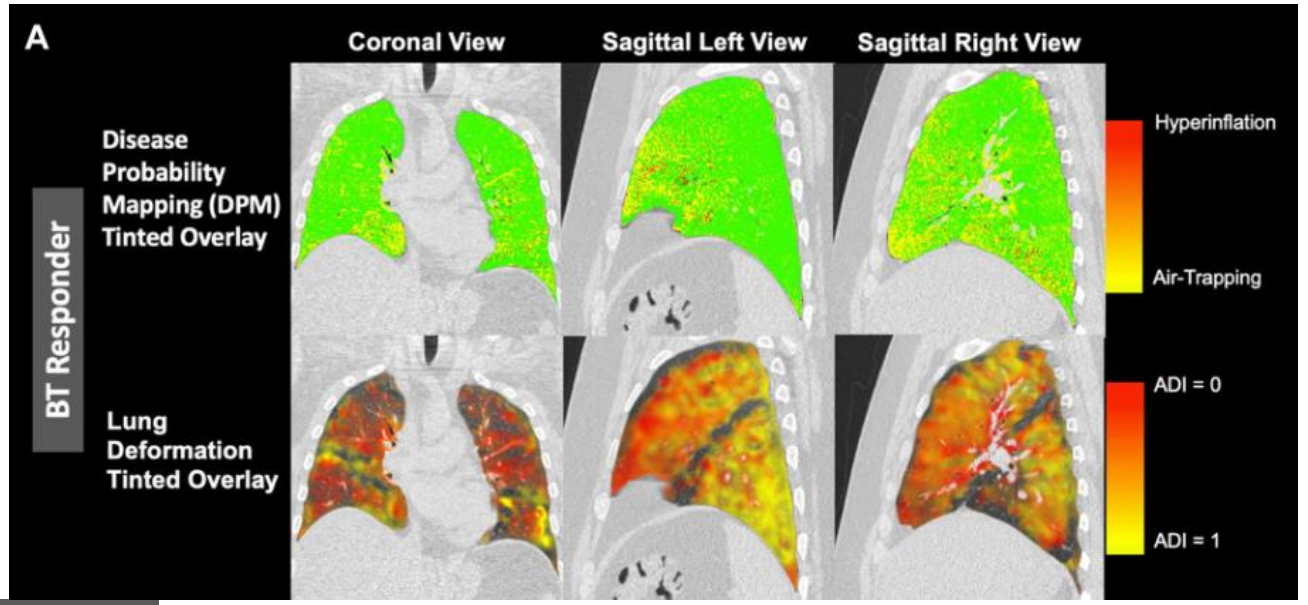


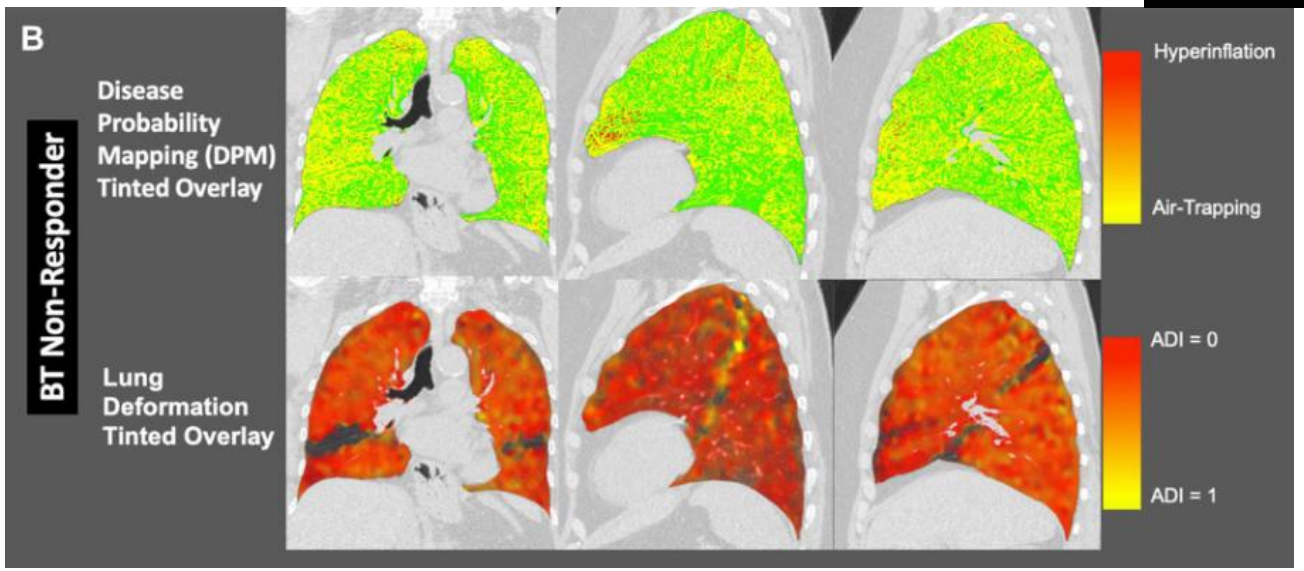




Kim et al. J Investig Allergol Clin Immunol 2018; Image was generated by ChatGPT

Patient selection : bronchial thermoplasty



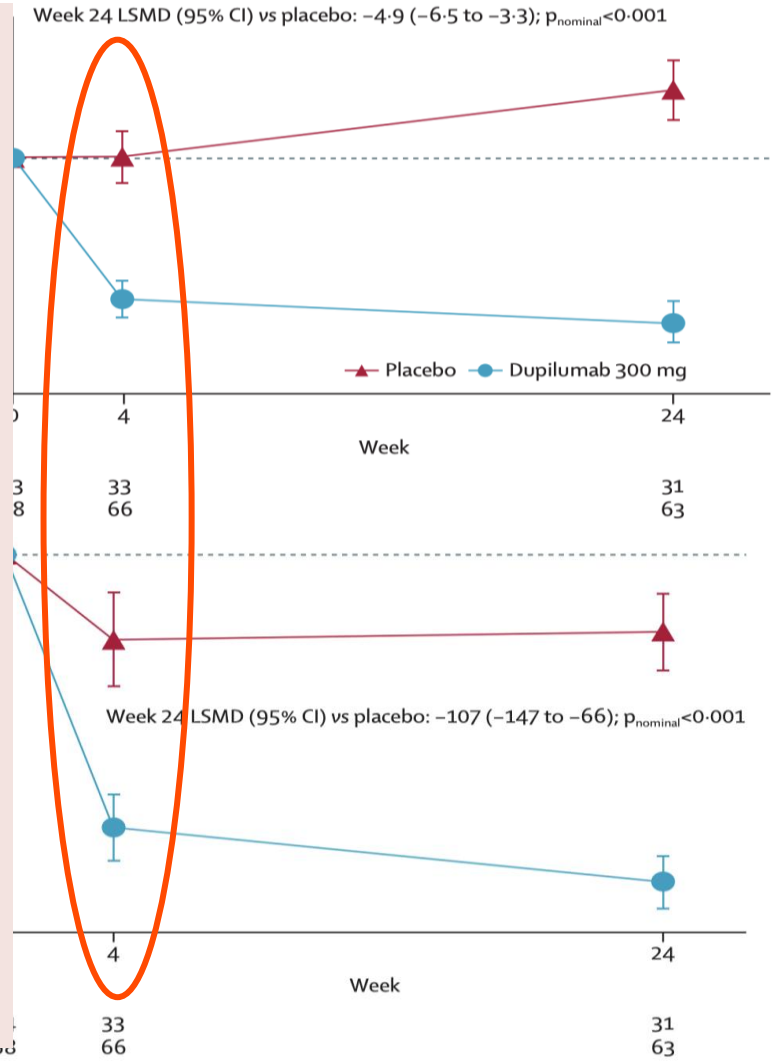


Samant et al. Chest 2024

Response: Improvement of mucus plug

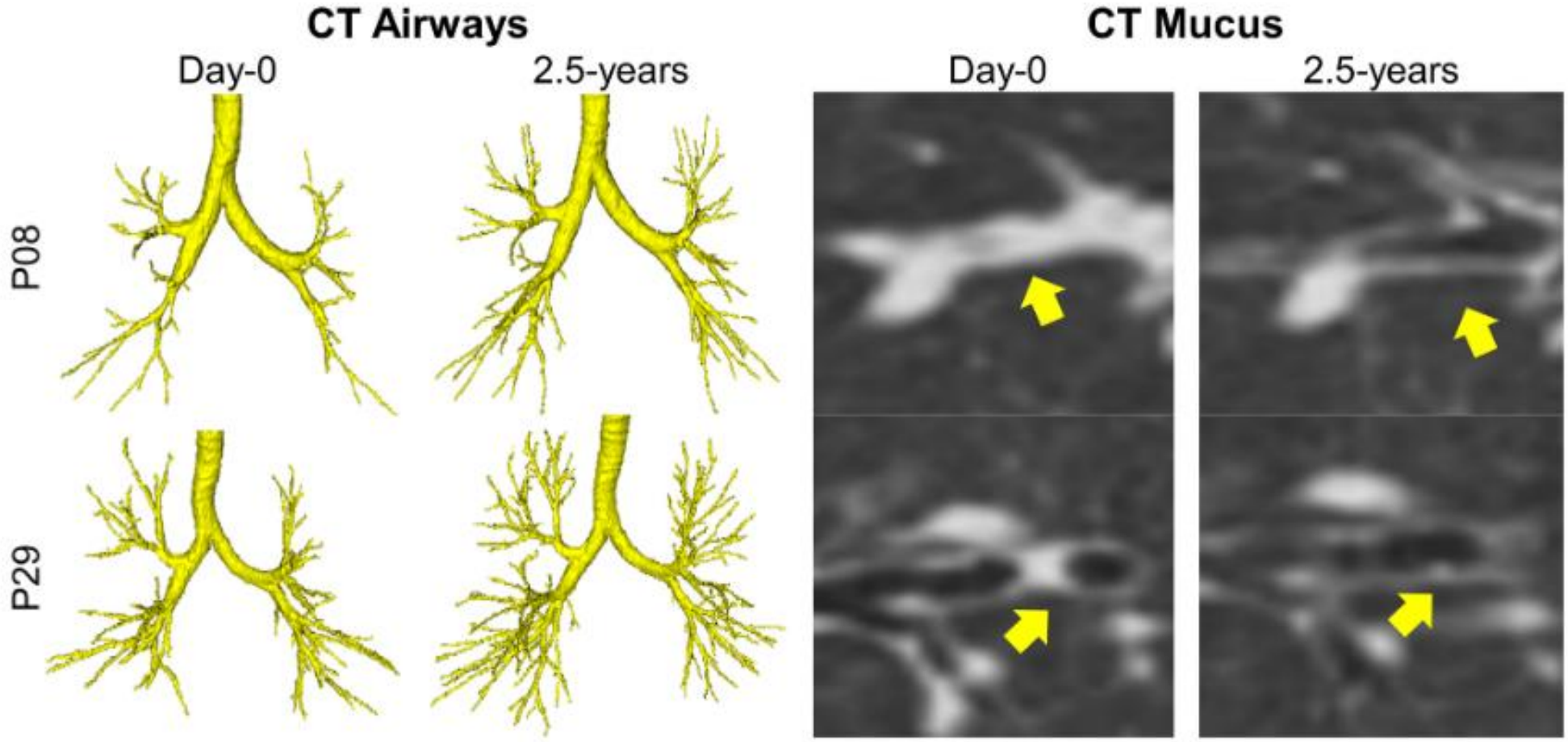
	Placebo (n=37)	Dupilumab 300 mg (n=72)
Change in (s)iV_{aw} at FRC		
Baseline, mean (SD), mL/L	0·9 (0·5)	0·9 (0·6)
Percentage change at week 4, LS mean (SE)	−11·7% (116·0)	209·5% (82·6)
LSMD (95% CI) *vs* placebo	..	221·2% (−57·0 to 499·4)
Percentage change at week 24, LS mean (SE)	−17·1% (129·4)	225·9% (92·3)
LSMD (95% CI) *vs* placebo	..	243·0% (−68·2 to 554·2)
p value *vs* placebo	..	$p_{nominal}$=0·12
Change in (s)iR_{aw} at TLC		
Baseline, median (IQR), kPa × s/L	0·4 (0·2 to 0·6)	0·4 (0·2 to 0·7)
Percentage change at week 4, median (IQR)	6·1% (−40·1 to 54·6)	−16·0% (−55·0 to 45·6)
Percentage change at week 24, median (IQR)	34·3% (−38·2 to 142·7)	−25·5% (−50·4 to 58·6)
Change in (s)iR_{aw} at FRC		
Baseline, median (IQR), kPa × s/L	0·3 (0·1 to 0·8)	0·3 (0·2 to 0·8)
Percentage change at week 4, median (IQR)	−20·1% (−60·4 to 157·0)	−35·7% (−68·5 to 35·1)
Percentage change at week 24, median (IQR)	16·7% (−47·9 to 123·9)	−21·0% (−64·1 to 31·6)

FRC=functional residual capacity. kPa=kilopascal. LS=least squares. LSMD=least squares mean difference. (s)iR_{aw}=trimmed distal airway resistance corrected for lung volume. (s)iV_{aw}=specific regional airway volumes corrected for lung volume. TLC=total lung capacity.



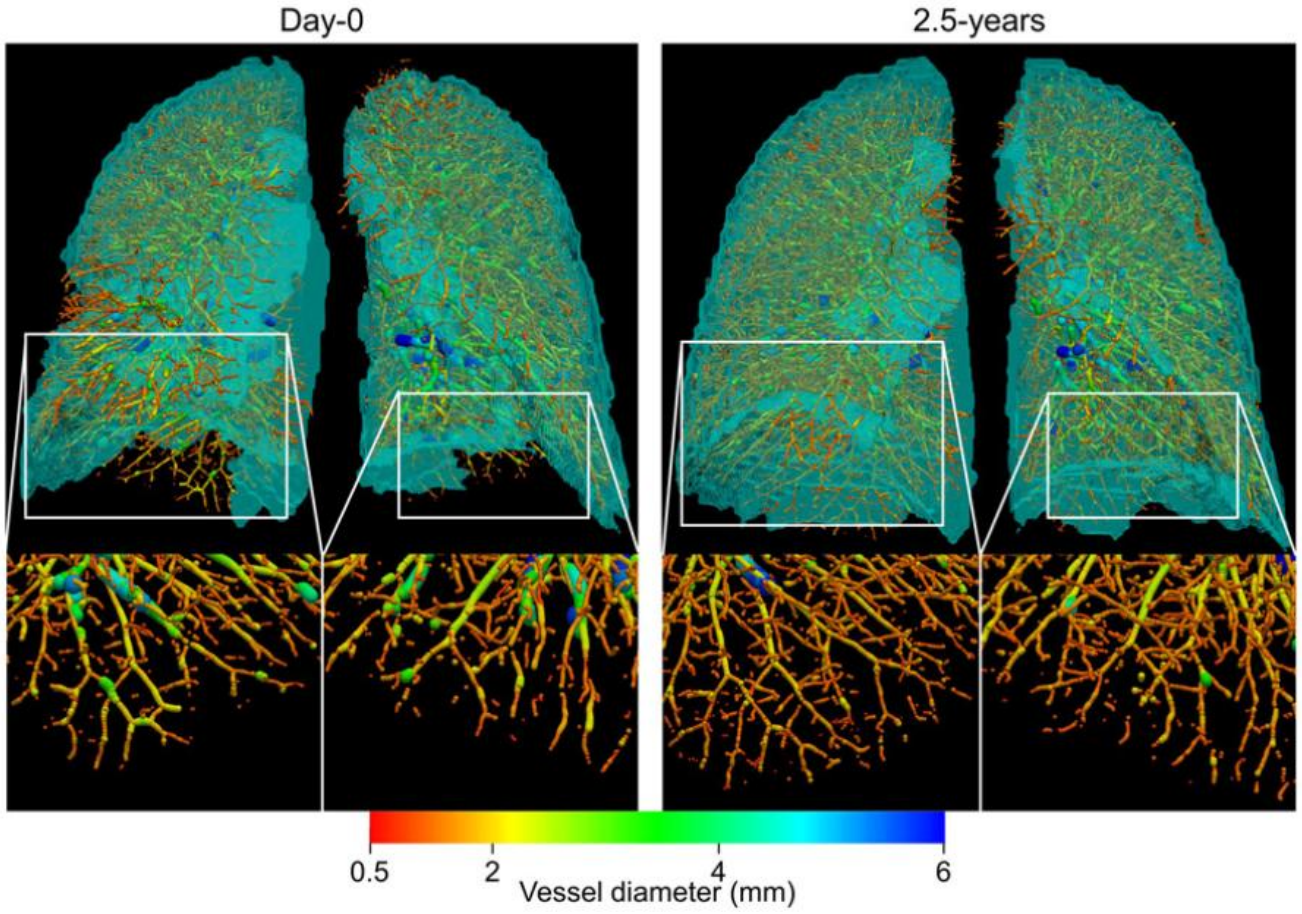
M. Castro et al. Lancet Respir Med. 2025

Response: TAC and mucus plug changes after 2.5 years of anti-IL-5Rα



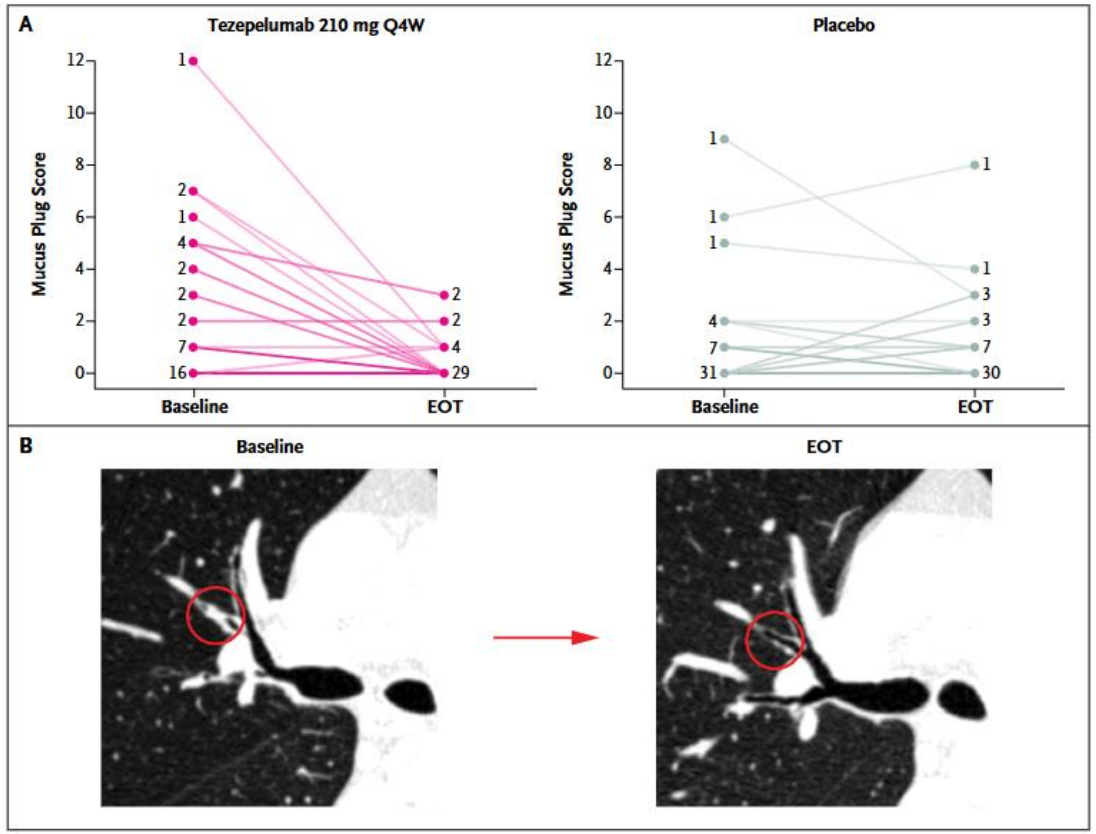
McIntosh et al. Chest 2023

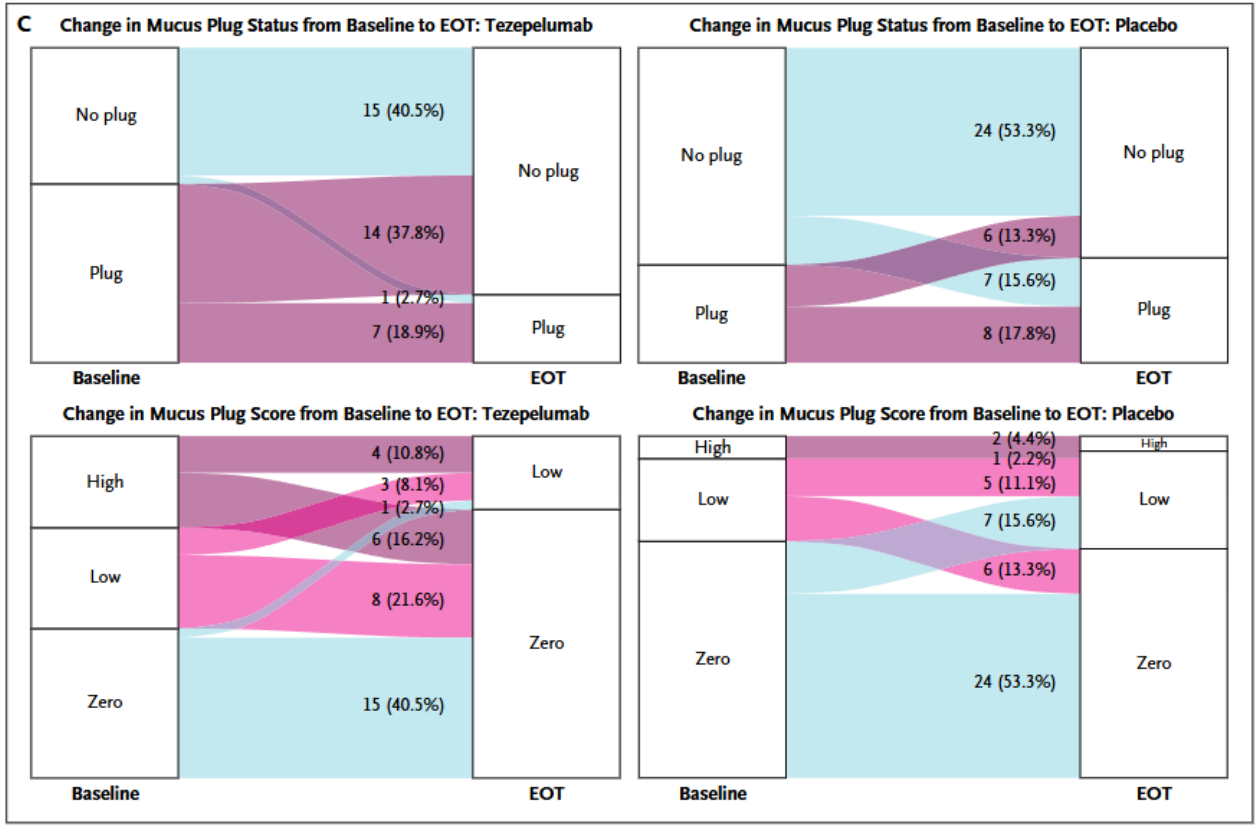
Response: vascular changes after 2.5 years of anti-IL-5Rα



McIntosh et al. AJRCCM 2023

Potential for Treatable Trait: Teze

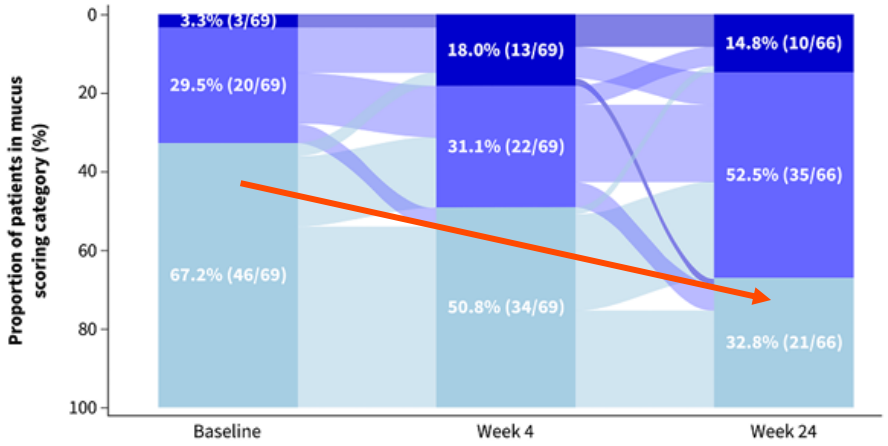




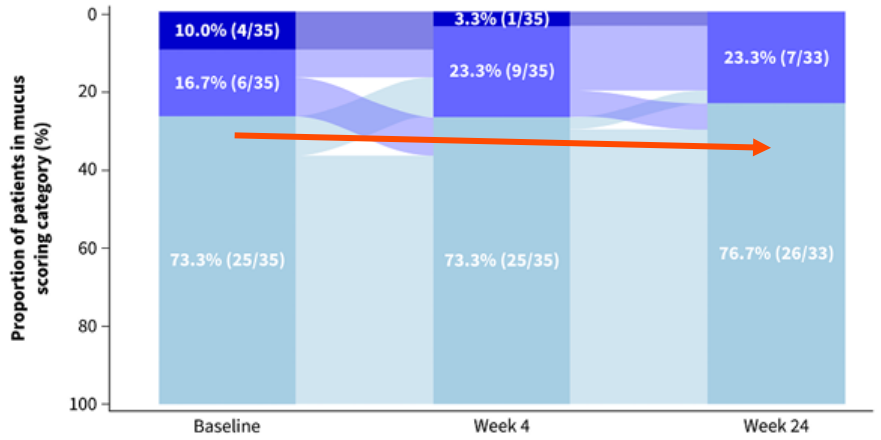
Nordenmark et al. NEJM Evid 2023

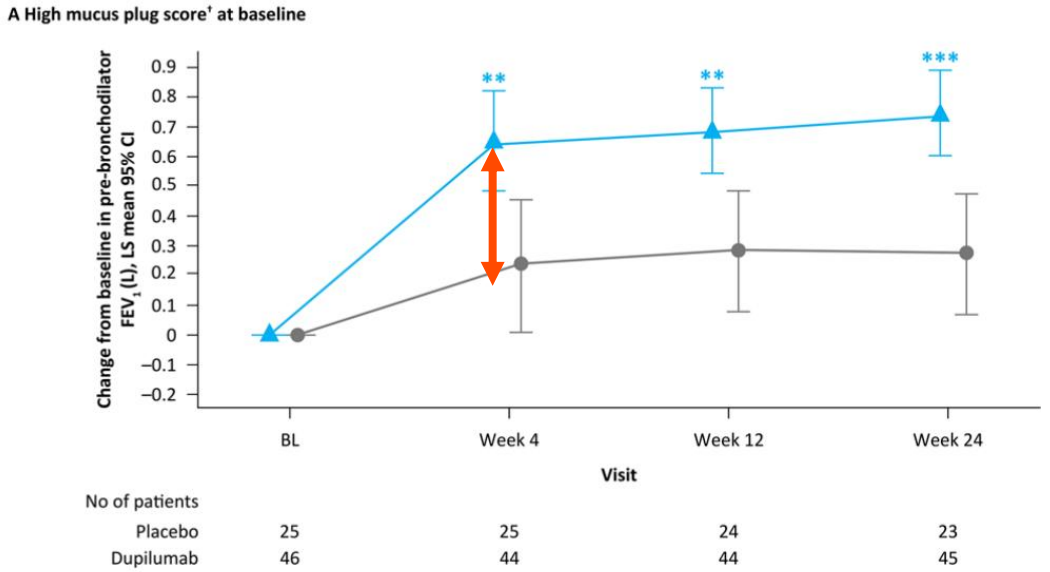
Potential for Treatable Trait: Dupi

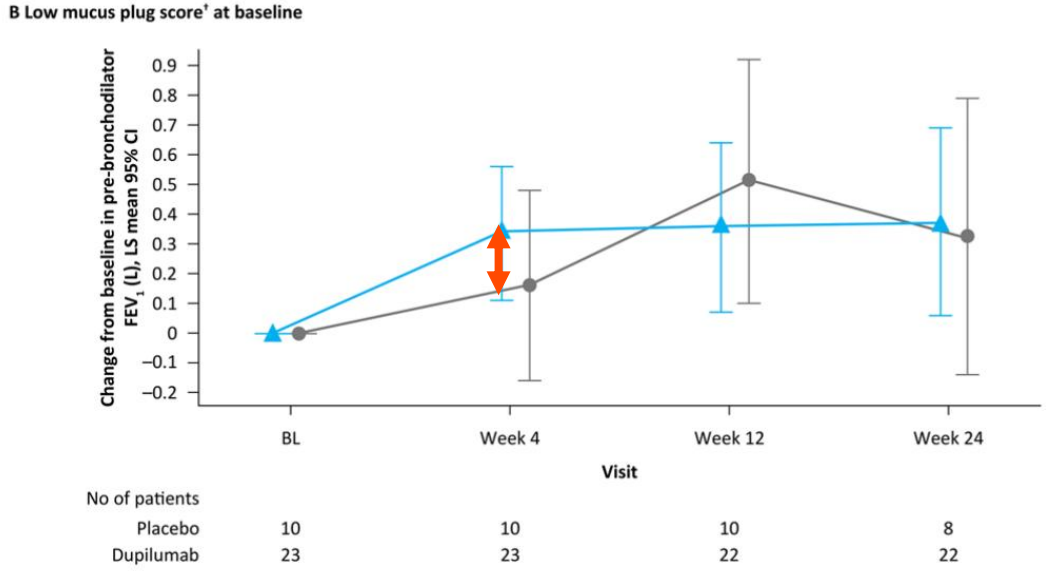
Dupilumab



Placebo

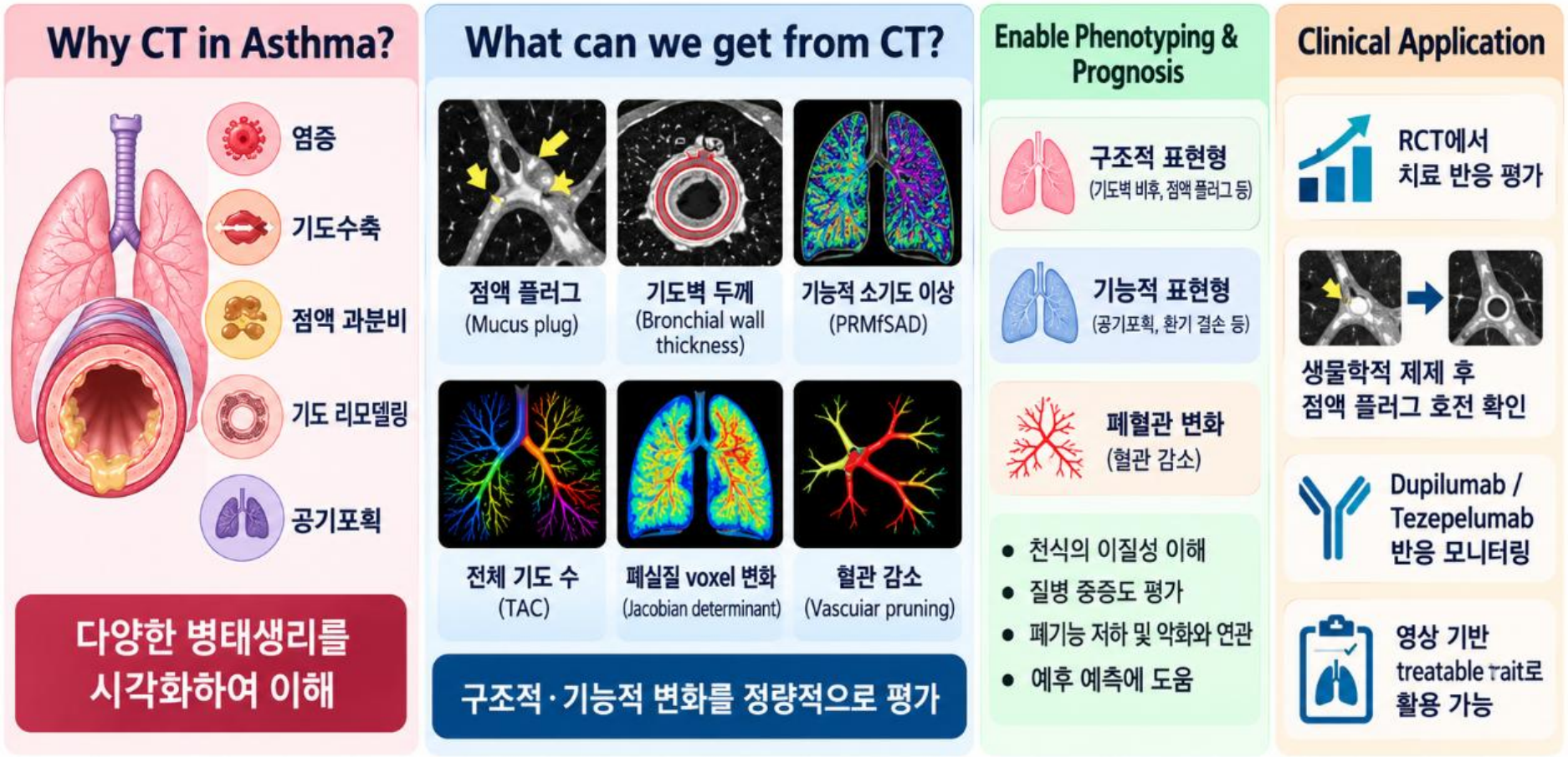






Porsbjerg et al. AJRCCM 2026

Summary



From structure to improvement of patients' care
qCT could compensate the current approach for asthma

Image was generated by ChatGPT