2024 Airway Symposium

Session II. Imaging analysis on airway disease in Korea

Looking at severe asthma through a window of computed tomography

Heung-Woo Park

Department of Internal Medicine,
Seoul National University College of Medicine

Conflict of Interest Disclosure

1. Participated in clinical trials & was a speaker for

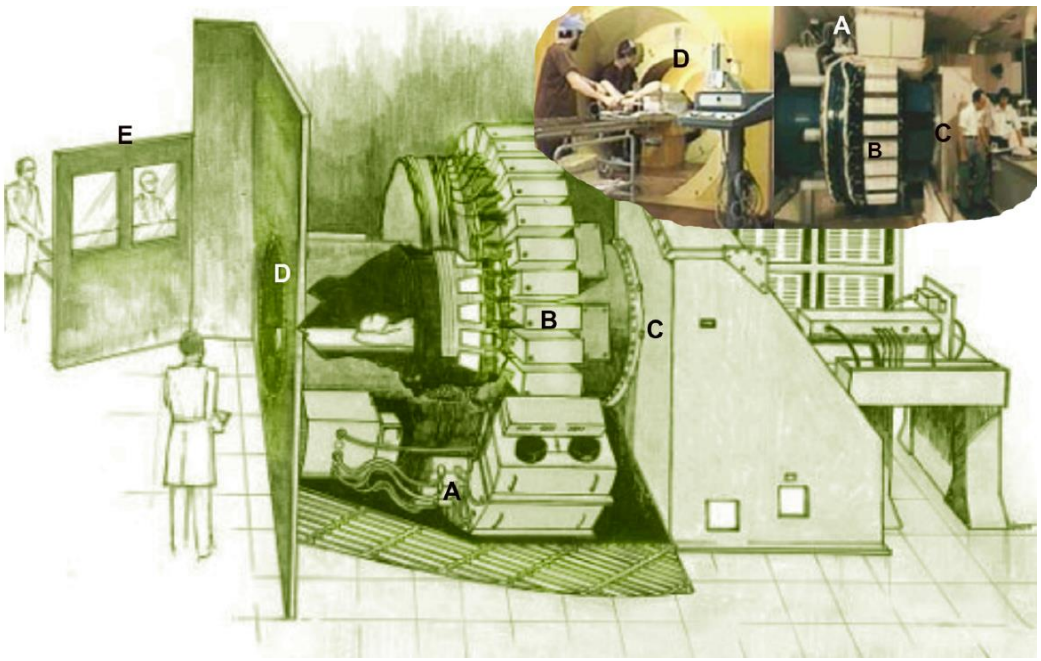
   AstraZeneca, Organon, GlaxoSmithKline, Novartis Sanofi & TEVA Korea

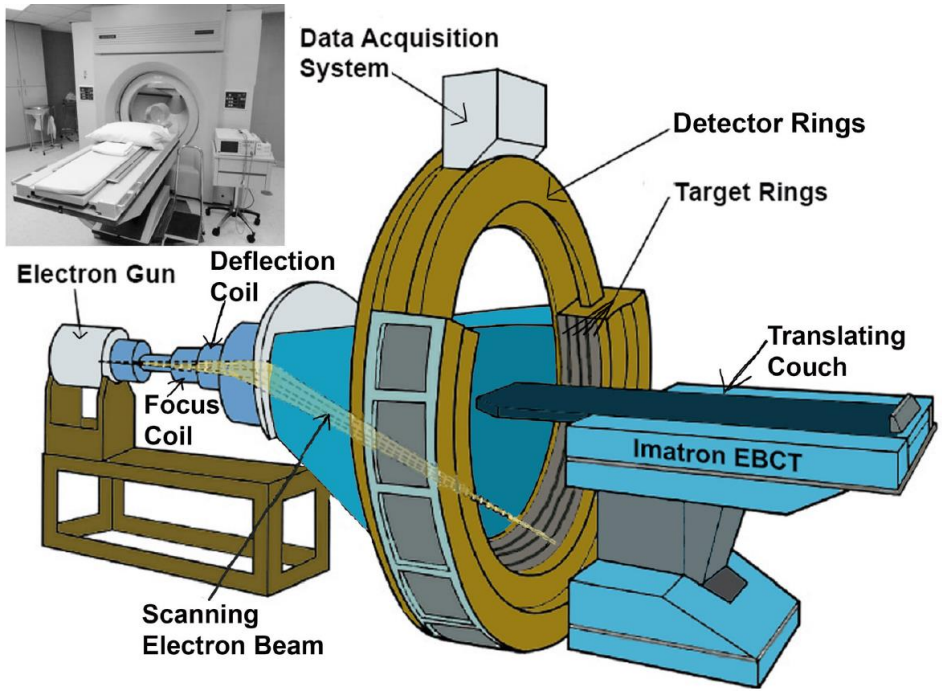
2. I declare that I have no conflict of interest related to this presentation

Overview

- Reasons why CT?
  - *What you see is what you get*
  - *Intelligence works in*
- Possible roles of CT
  - *Objective measurements*
  - *Phenotyping*
  - *Prediction*
  - *Other than airway*
- Limitations & Conclusions

Computed tomography





Br J Radiol 2022;95:20211364

Reasons why CT; *What you see is what you get*

HRCT를 이용한 천식의 중증도에 따른 기도개형의 평가

성균관대학교 의과대학 내과학교실 강북삼성병원 호흡기내과[1],
중앙대학교 의과대학 방사선과학교실[2], 내과학교실[3]

임성용[1] · 김양수[2] · 최병휘[3]

Background : Airway remodeling is characterized by an increase in the airway wall thickness. We aimed to compare the airway wall thickness among asthmatic subjects with different severity and to examine its relation to pulmonary function and airway hyperresponsiveness.

Methods : Thirty-seven adult asthmatics were assigned to mild (MA, n=17), moderate (MoA, n=11), and severe (SA, n=9) groups according to the Global Initiative for Asthma classification. Patients with more than 10 pack-years of smoking history were excluded. We measured the airway wall thickness (T) and internal diameter (d) using high-resolution computed tomography, and then calculated the external diameter (D). The T/D ratio was compared between the groups and correlations between the T/D ratio and pulmonary function (methacholine PC_{20}) were assessed.

Results : The mean T/D ratio was significantly higher in the MoA and the SA groups than in the MA group for the total airways (0.278±0.014, 0.281±0 .019 vs. 0.228±0.013; p=0.022, p=0.021, respectively). The mean T/D ratio was also higher in the SA group than the MA group for the small airways (0.313±0.018 vs. 0.253±0.013; p=0.009). However, there were no significant differences for the large airways. The mean T/D ratio negatively correlated with FEV_1 (L) and FEV_1 (% of predicted) in total airways (r=−0.519, p=0.001; r=−0.396, p=0.015), small airways (r=−0.567, p<0.001; r=−0.450, p=0.008) and large airways (r=−0.395, p=0.015; r=−0.351, p=0.033). The methacholine PC_{20} was not related to the T/D ratio.

Conclusions : This study suggests that patients with moderate to severe asthma have greater airway remodeling than those with mild asthma, and the degree of airway wall thickening correlates to the severity of airflow obstruction. (Korean J Med 73:631-637, 2007)

Korean J Med 2007;73:631-7

Reasons why CT; *What you see is what you get*

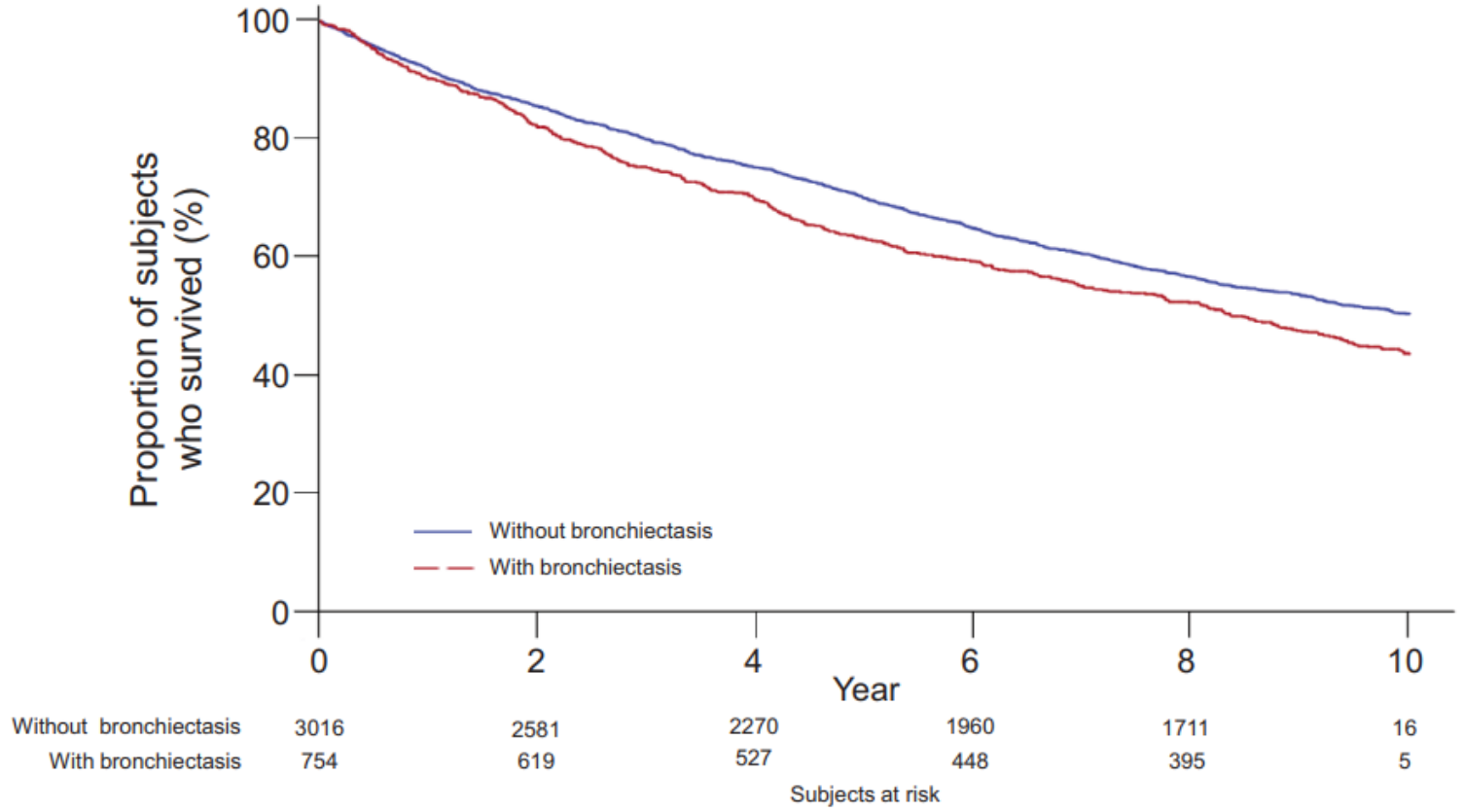
- **Children with severe asthma have substantial structural airway changes on CT**

Characteristics	Automatic analysis (N=142)	Manual analysis (N=162)
Inspiration		
Bronchiectasis	116 (81.7%)	45 (28%)
Airway wall thickening	138 (97.2%)	143 (88.8%)
Mucus plugging	-	52 (32.3%)
Expiration		
Low attenuation area	142 (100%)	121 (82.9%)
%CT's with >5% air trapping	100 (81.3%)	63 (43.2%)

ERJ Open Res 2024;10:00121-2023

Reasons why CT; *What you see is what you get*

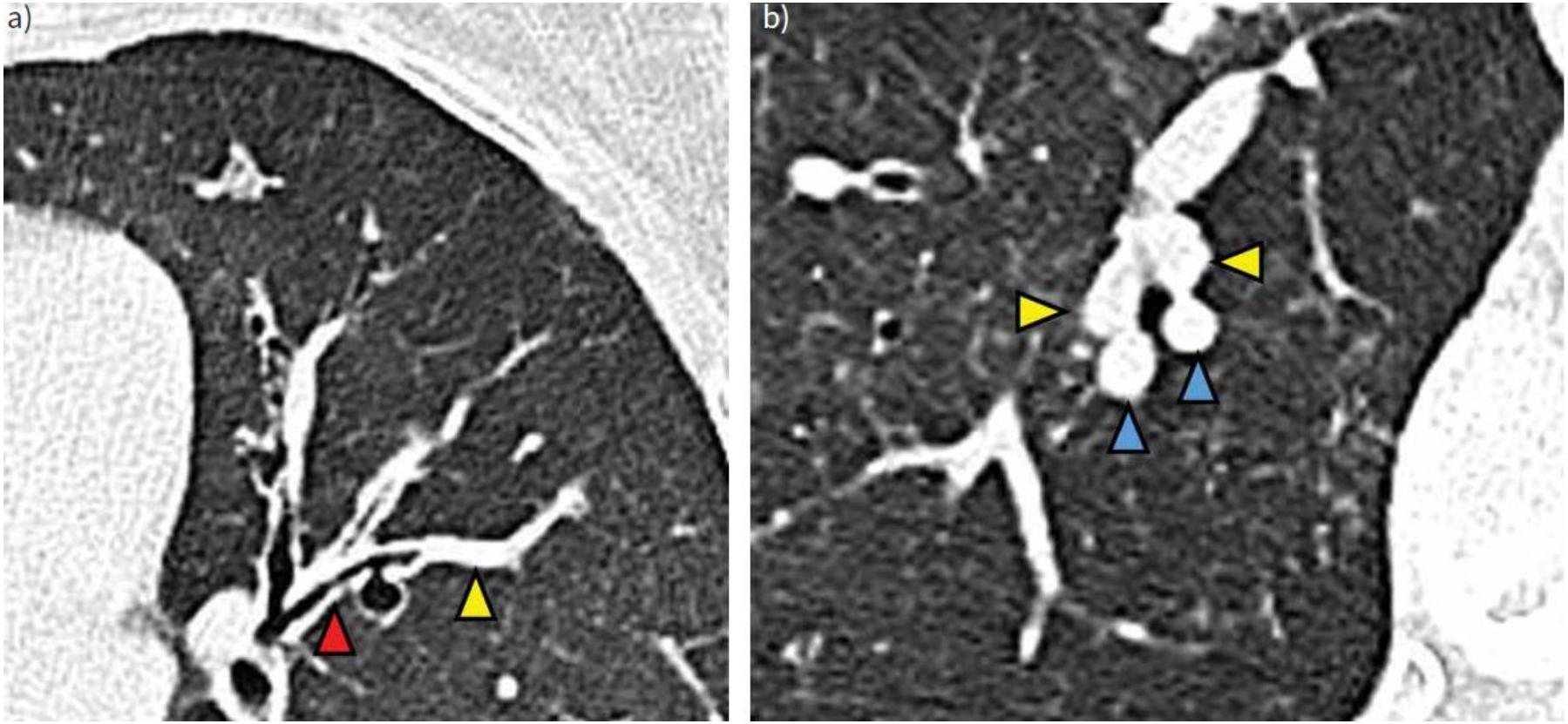
- **Co-morbidities… Bronchiectasis**



Kim SH, et al. Ther Adv Respir Dis 2020:14:1753466620963030

Reasons why CT; *What you see is what you get*

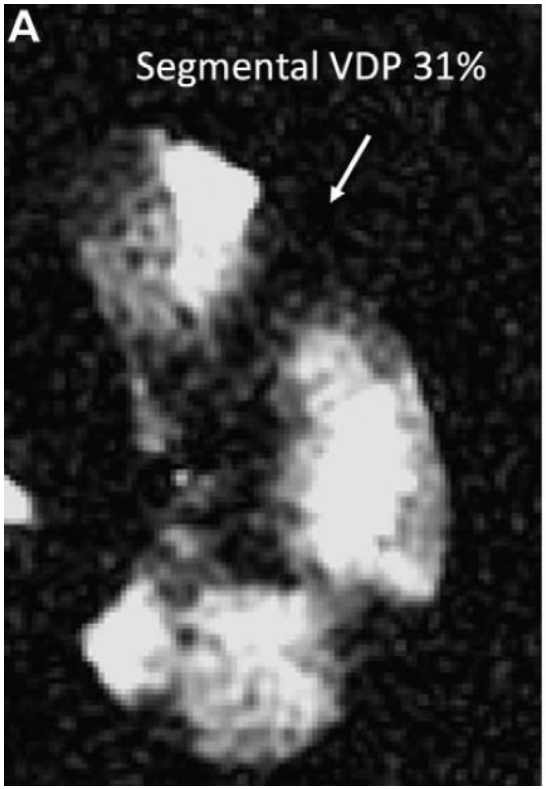
- **Mucus plugging**

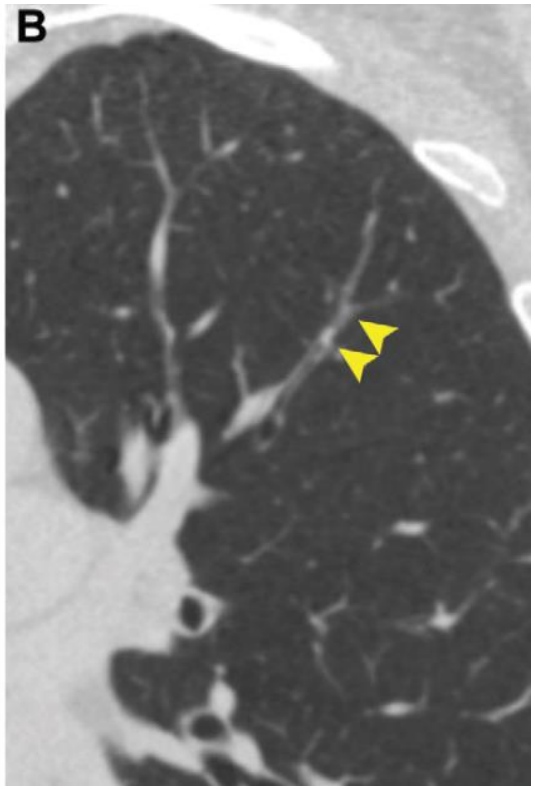


Breathe (Sheff) 2024;20:240033

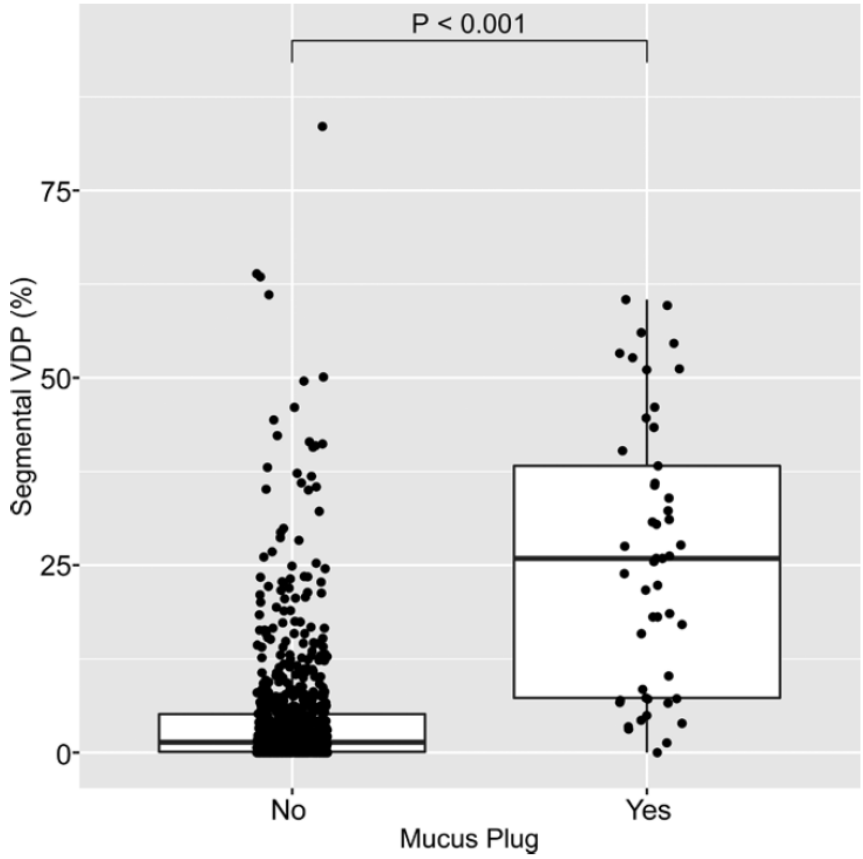
Reasons why CT; *What you see is what you get*

- **Mucus plugging**





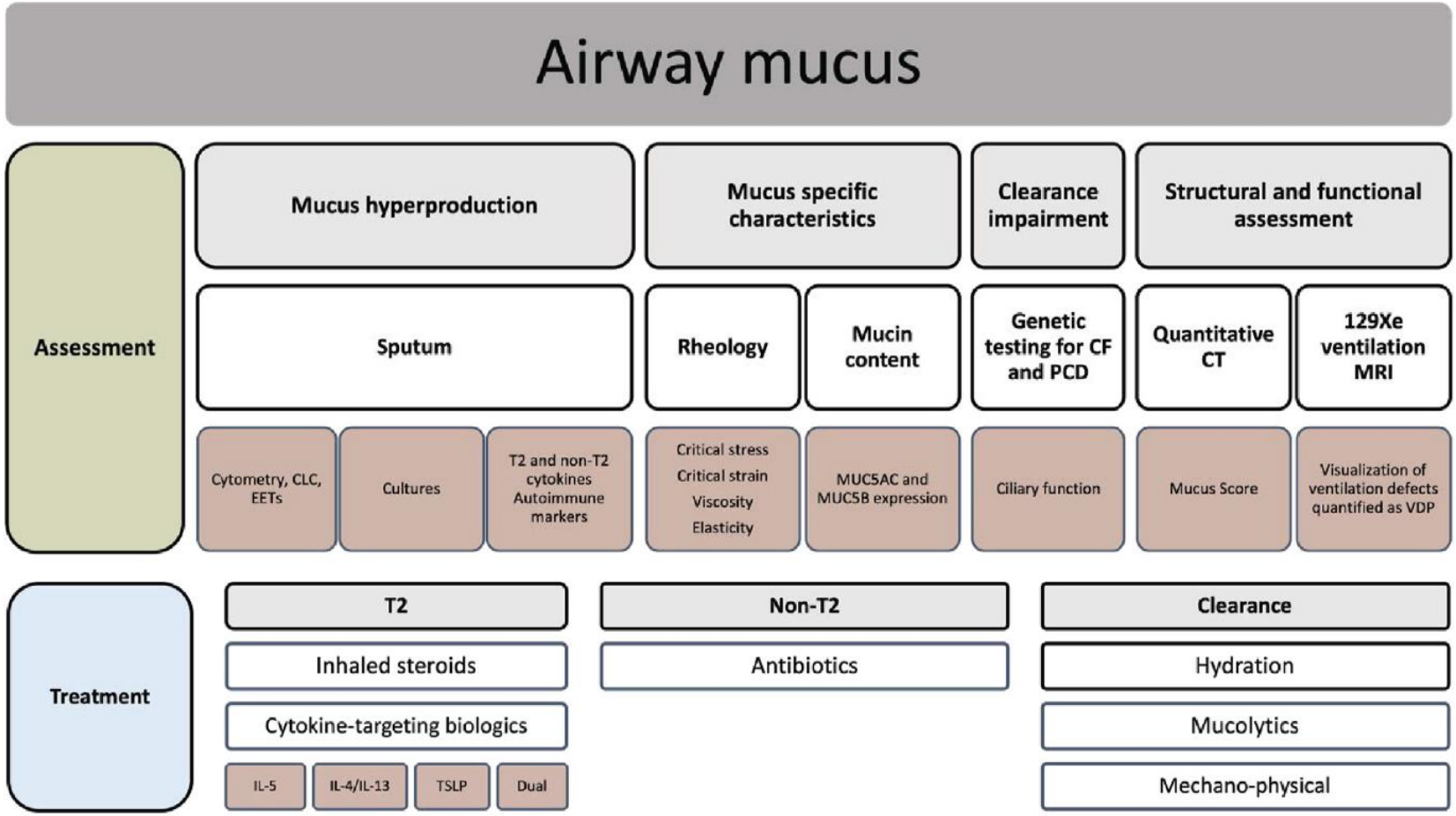
VDP: Ventilation defect %



Radiology 2022;303:184-90

Reasons why CT; *What you see is what you get*

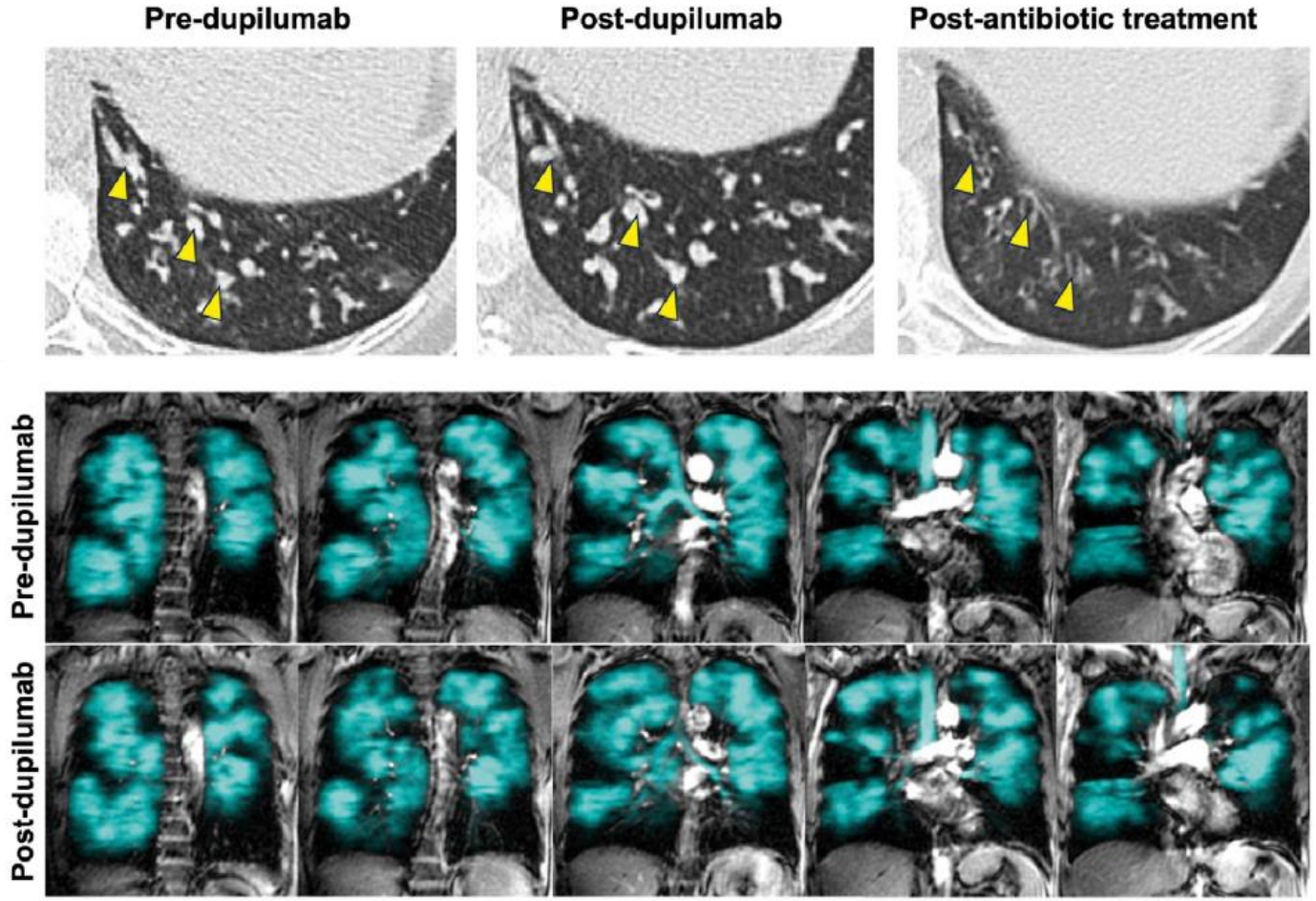
- **Mucus plugging**



Allergol Int 2024;73:351-61

Reasons why CT; *What you see is what you get*

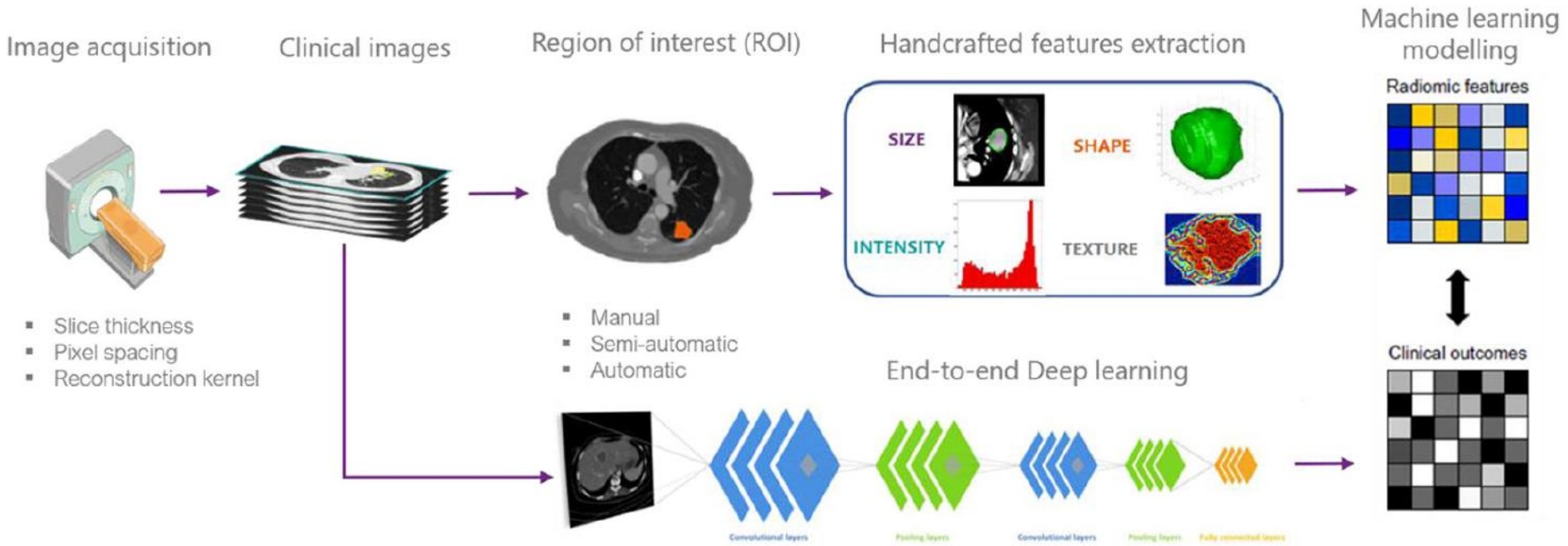
- **Functional imaging**



Allergol Int 2024;73:351-61

Reasons why CT; *Intelligence works in*

- **Radiomics**

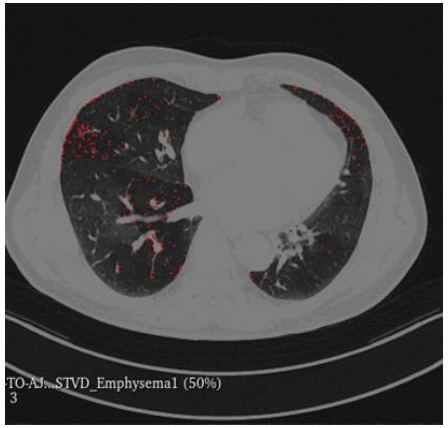


Med Res Rev 2022;42:426-40

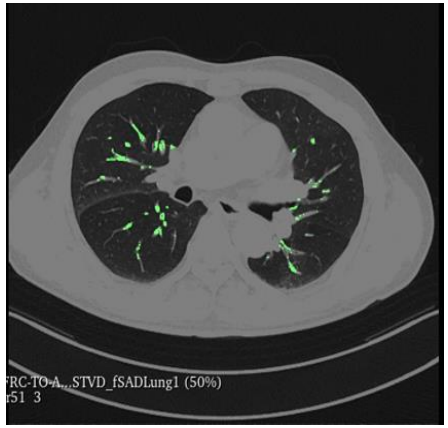
Possible roles of CT; *Objective measurements*

- **Relationship of CT-based measurements with symptom perception & QOL in patients with severe asthma**

Parenchymal variables

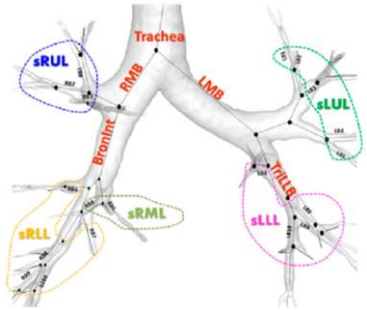


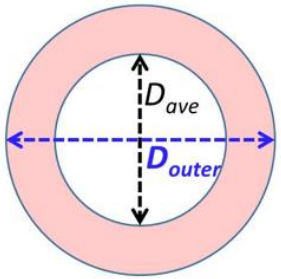
Emphysematous lung (Emph)



Functional small airway disease of lung (fSAD)

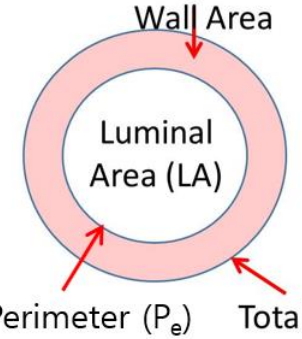
Structural variables





$$WT = D_{outer} - D_{ave}$$

Wall thickness (WT)



$$D_h = \frac{4 \times LA}{P_e}$$

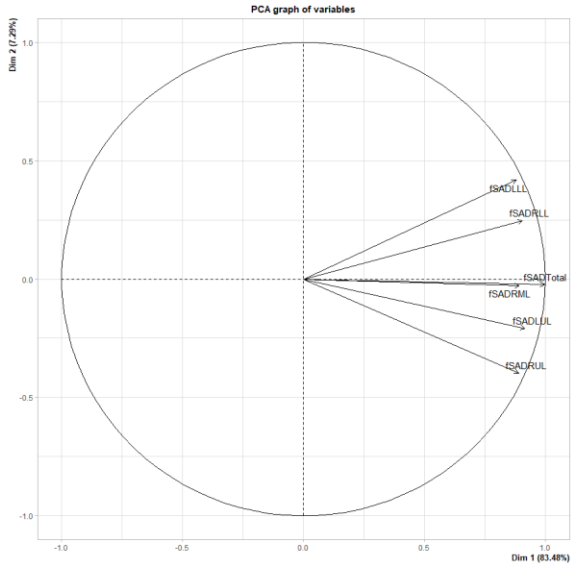
Hydraulic diameter (Dh)

Jeong J, Nam YH, Park HW, Kim SH, et al. Respir Med 2024:225:107598

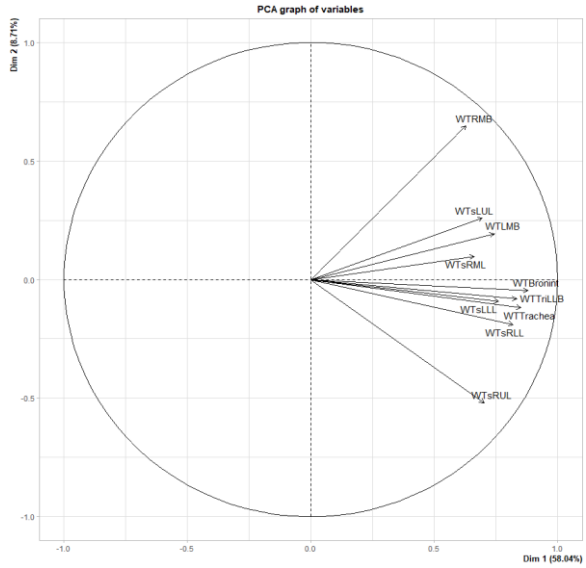
Possible roles of CT; *Objective measurements*

- **Relationship of CT-based measurements with symptom perception & QOL in patients with severe asthma**

1st Principal component



Functional small airway disease of lung (fSAD)



Wall thickness (WT)

Jeong J, Nam YH, Park HW, Kim SH, et al. Respir Med 2024:225:107598

Possible roles of CT; *Objective measurements*

- **Relationship of CT-based measurements with symptom perception & QOL in patients with severe asthma**

Associations between symptom perception and lung function and between symptom perception and CT-based measurements.

	Cough			Dyspnea			Wheeze			Sputum		
	Coef	P	adj P	Coef	P	adj P	Coef	P	adj P	Coef	P	adj P
FEV1	−0.010	0.92	0.95	−0.097	0.34	0.41	0.074	0.47	0.35	−0.075	0.46	0.34
FEV1p	−0.031	0.76	0.58	−0.10	0.31	0.48	0.17	0.10	0.15	−0.16	0.12	0.20
FVC	0.059	0.56	0.42	−0.015	0.88	0.97	0.077	0.45	0.25	−0.03	0.76	0.57
FVCp	0.071	0.49	0.62	−0.0092	0.93	0.84	0.22	**0.027**	0.074	−0.08	0.45	0.66
Ratio	−0.15	0.15	0.12	−0.17	0.090	0.15	−0.021	0.84	0.85	−0.13	0.19	0.14
WT[a]	0.19	**0.037**	**0.020**	0.067	0.52	0.35	0.13	0.20	0.22	0.074	0.48	0.34
Dh[a]	−0.14	0.19	0.30	−0.025	0.81	0.79	−0.071	0.50	0.39	−0.12	0.27	0.16
Emph%[b]	−0.16	0.16	0.079	−0.070	0.54	0.44	−0.10	0.37	0.45	−0.04	0.74	0.31
fSAD%[b]	−0.009	0.94	0.86	0.25	**0.028**	**0.044**	0.024	0.83	0.93	0.090	0.43	0.48

Jeong J, Nam YH, Park HW, Kim SH, et al. Respir Med 2024:225:107598

Possible roles of CT; *Objective measurements*

- **Relationship of CT-based measurements with symptom perception & QOL in patients with severe asthma**

Associations between quality of life and lung function and between quality of life and CT-based measurements.

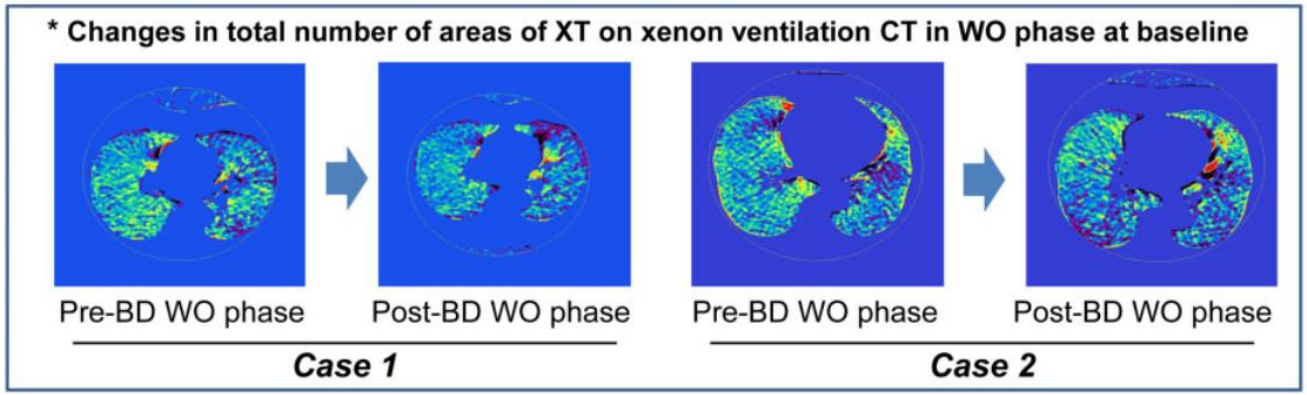
	SAQ life			SAQ mind			SAQ body			SAQ		
	Coef	P	adj P	Coef	P	adj P	Coef	P	adj P	Coef	P	adj P
FEV1	0.13	0.21	0.055	−0.039	0.71	0.60	0.12	0.25	0.11	0.084	0.41	0.13
FEV1p	0.12	0.18	0.12	0.18	0.23	0.22	0.20	0.10	0.056	0.14	0.18	0.081
FVC	0.11	0.29	0.091	−0.10	0.64	0.97	0.087	0.39	0.15	0.044	0.67	0.23
FVCp	0.19	**0.049**	0.058	0.065	0.53	0.32	0.19	0.062	0.090	0.17	0.10	0.18
Ratio	0.032	0.76	0.50	0.016	0.88	0.58	−0.019	0.87	0.44	0.016	0.87	0.50
WT[a]	−0.21	**0.044**	0.087	−0.24	**0.029**	**0.037**	−0.19	0.061	0.12	−0.23	**0.027**	**0.042**
Dh[a]	0.086	0.41	0.94	−0.015	0.89	0.79	0.0090	0.93	0.61	0.035	0.73	0.58
Emph[b]	−0.06	0.63	0.48	−0.16	0.066	0.098	−0.24	**0.024**	**0.031**	−0.26	**0.027**	**0.045**
fSAD[b]	−0.078	0.49	0.57	0.084	0.46	0.47	−0.084	0.88	0.51	0.052	0.74	0.49

Jeong J, Nam YH, Park HW, Kim SH, et al. Respir Med 2024:225:107598

Possible roles of CT; *Objective measurements*

- **Xenon ventilation computed tomography & the management of asthma in the elderly**

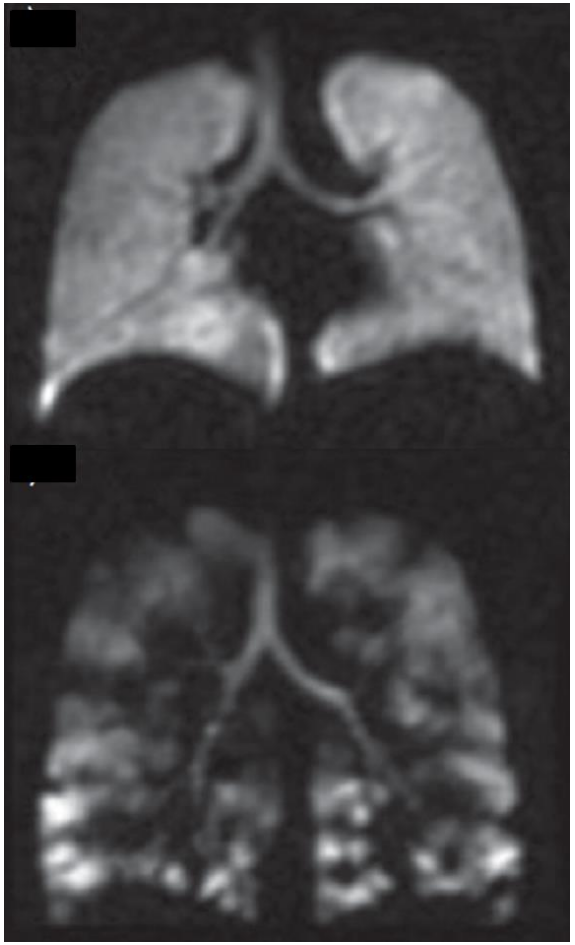
	Case 1 66-year, female	Case 2 65-year, female
At baseline		
PC_{20} (mg/mL)	1.29	5.19
FEV_1% predicted	65	66
% Increase in FEV_1 after BD inhalation	5	-1
After 12-week treatment		
FEV_1% predicted	116	78
% Increase in FEV_1 after treatment	78	18

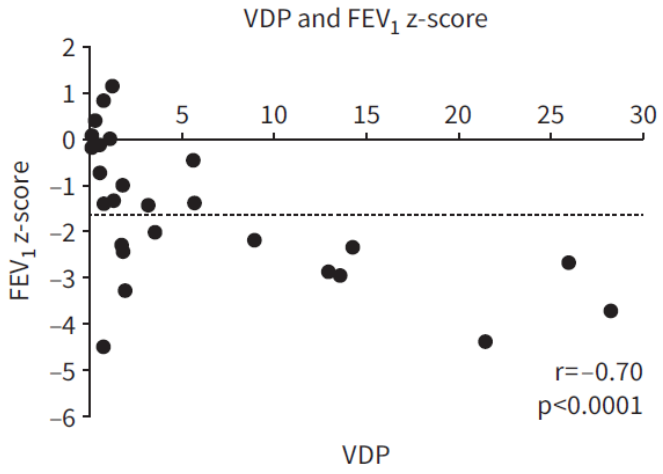


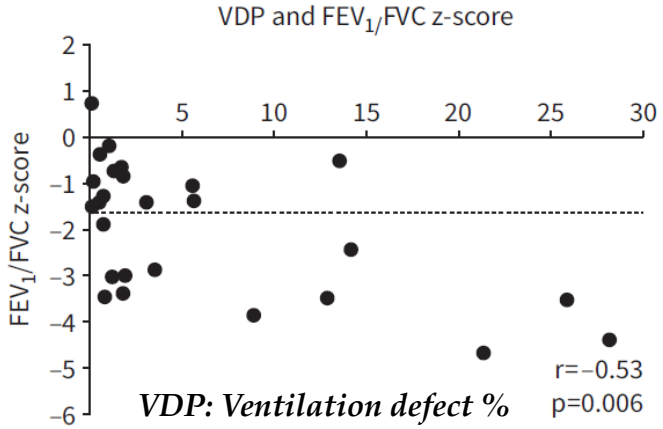
Park HW, Cho SH, et al. Respirology 2014;19:389-95

Possible roles of CT; *Objective measurements*

- **Xenon ventilation MRI in severe asthma**



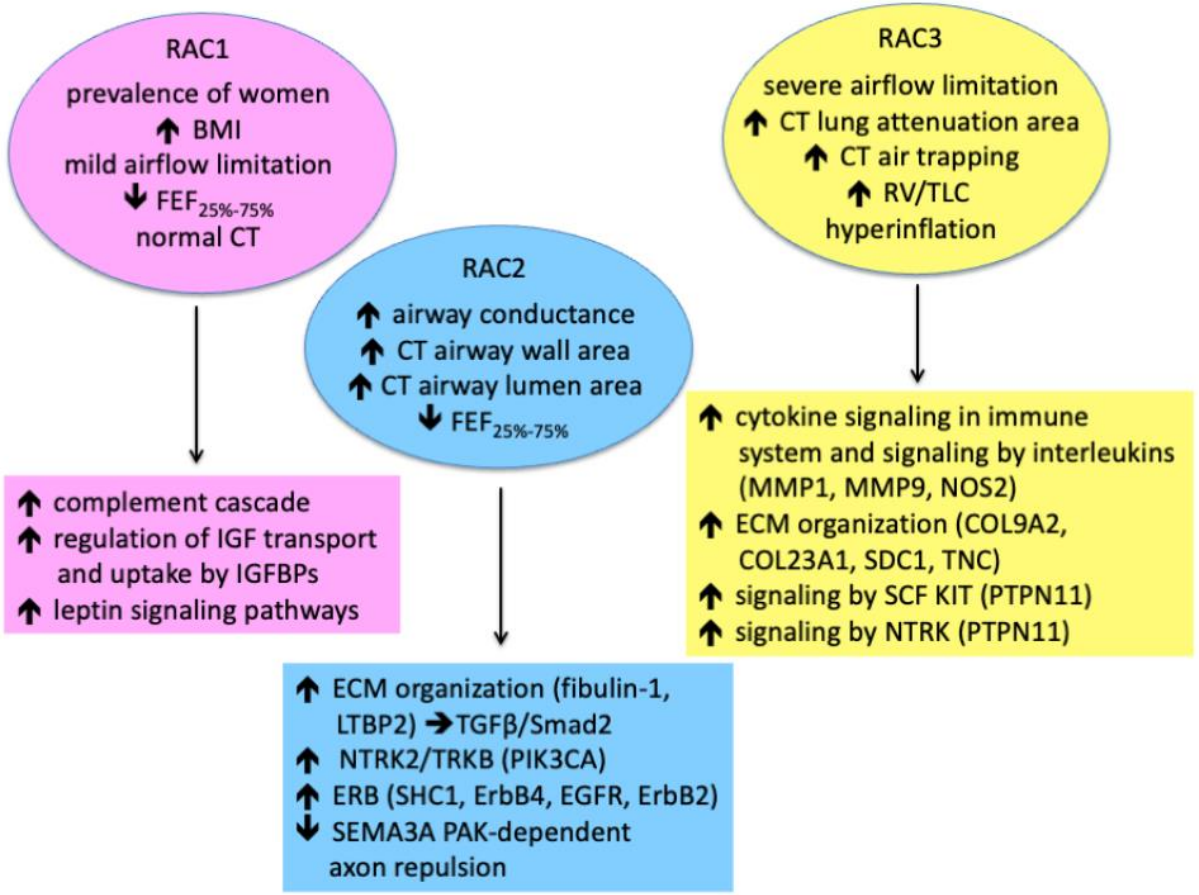




ERJ Open Res 2021;7:00785-2020

Possible roles of CT; *Phenotyping*

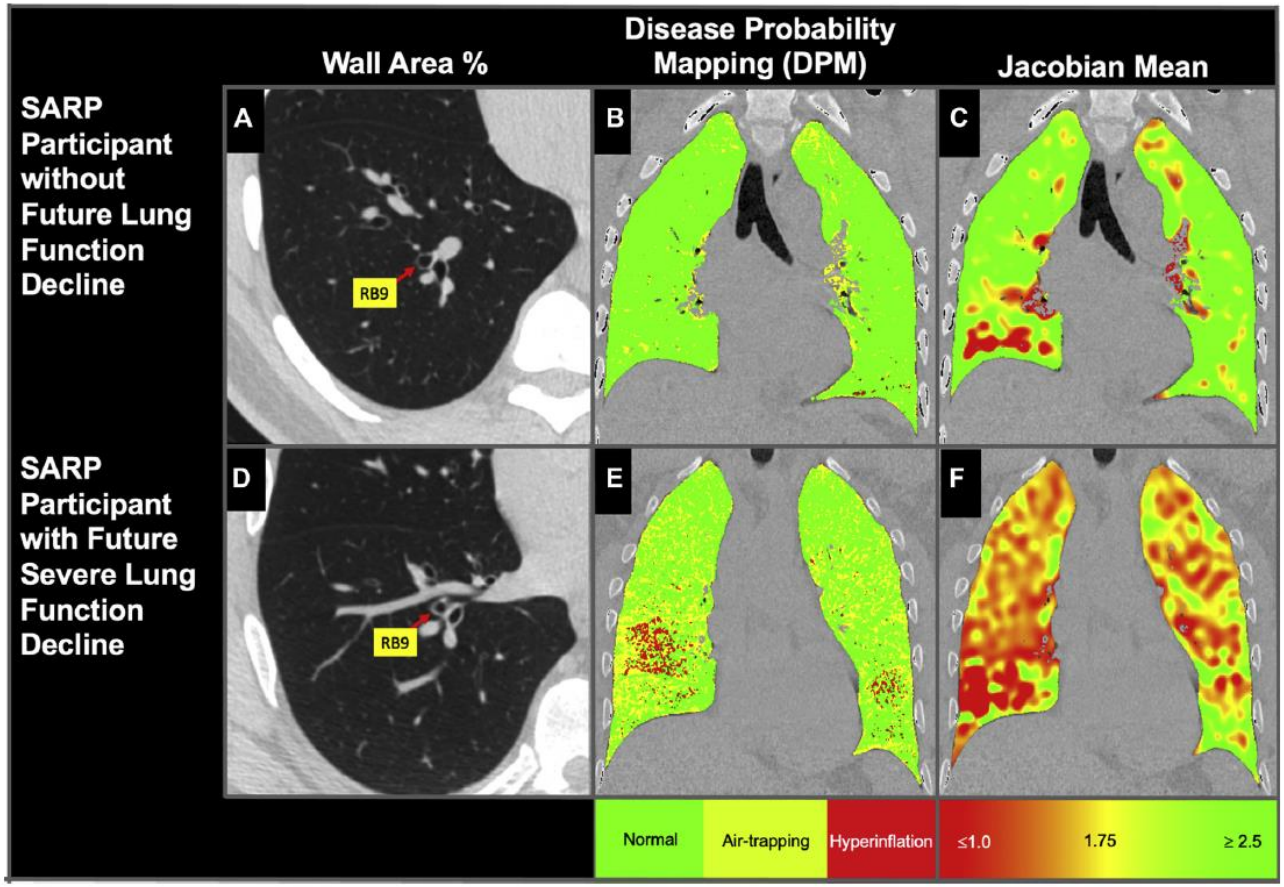
- **Radiomultiomics: quantitative CT clusters of severe asthma associated with multi-omics**



Eur Respir J 2024 Oct 10:2400207 (Online ahead of print)

Possible roles of CT; *Prediction*

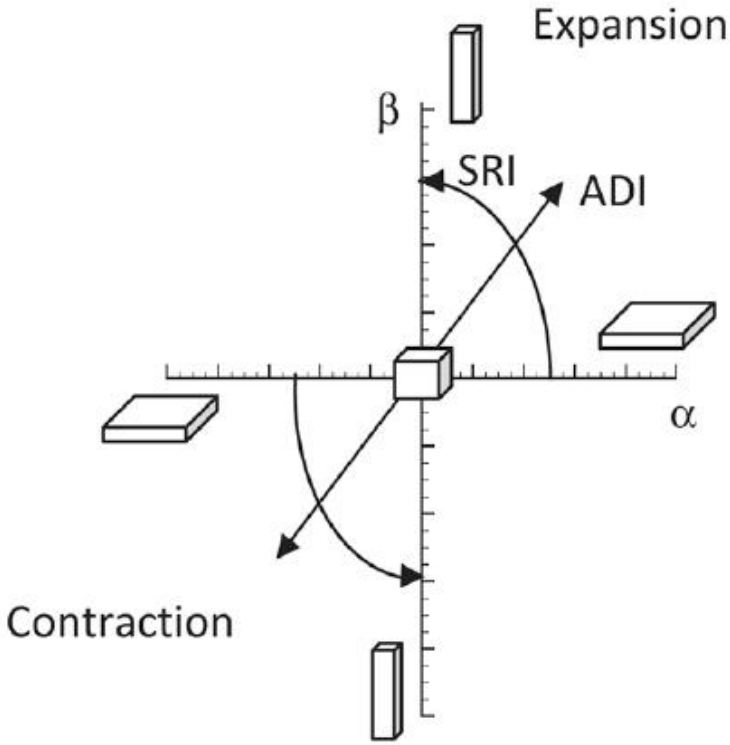
- **Quantitative CT metrics are associated with longitudinal lung function decline & future asthma exacerbations**



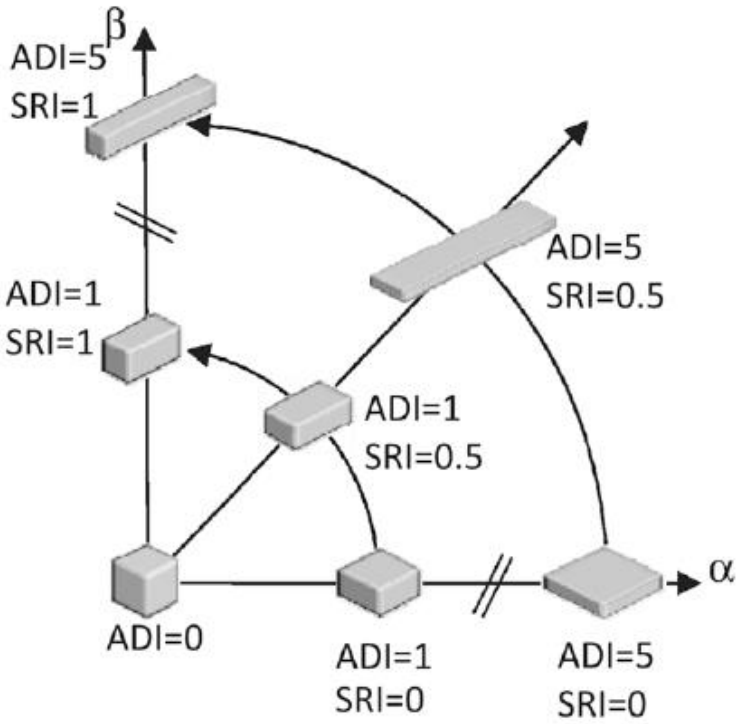
J Allergy Clin Immunol 2021;148:752-62

Possible roles of CT; *Prediction*

- **Quantitative CT metrics are associated with longitudinal lung function decline & future asthma exacerbations**



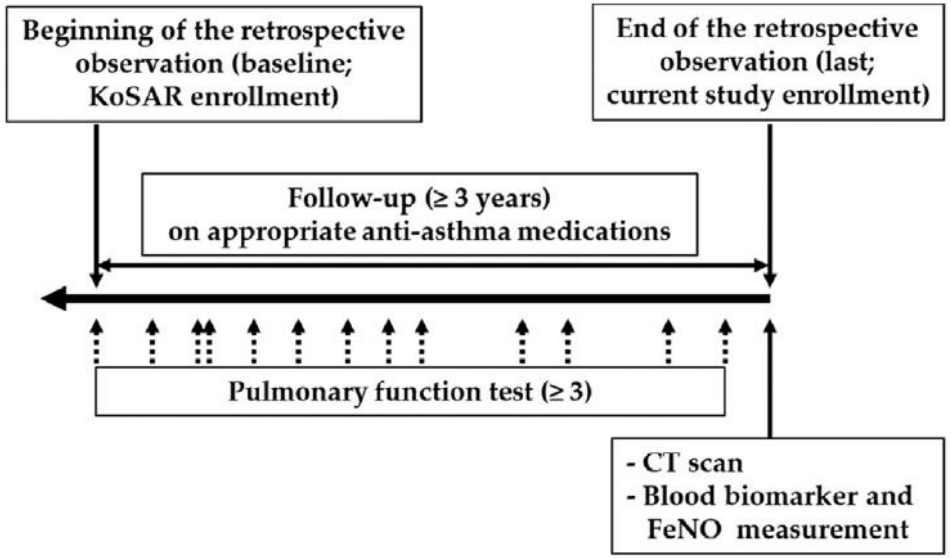
Anisotropic Deformation Index

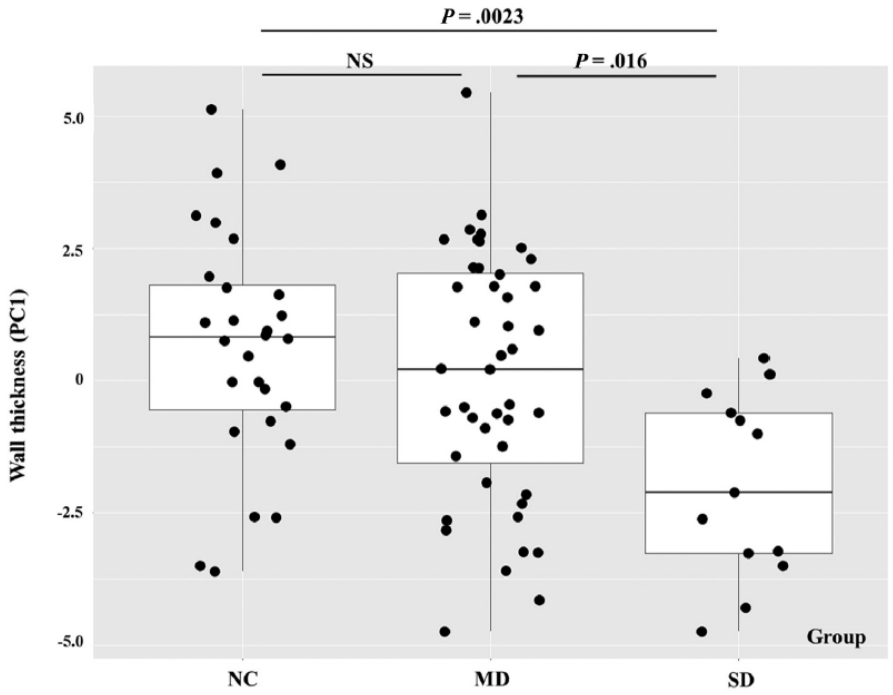


Slab-Rod Index

Possible roles of CT; *Prediction*

- **CT-based measurements associated with rapid lung function decline in severe asthma**





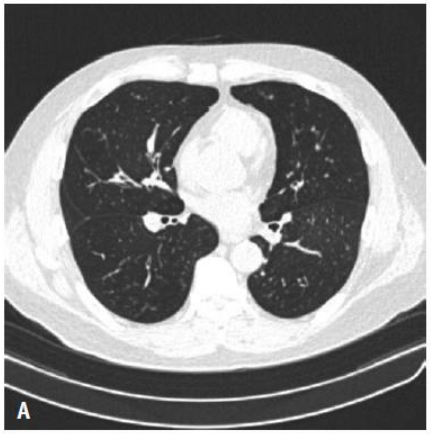
Wall thickness

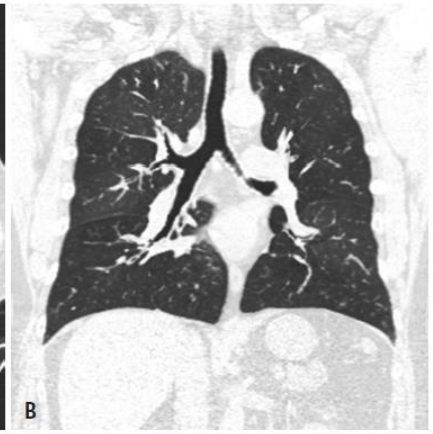
(NC; no change, MD; mild decline, SD; severe decline)

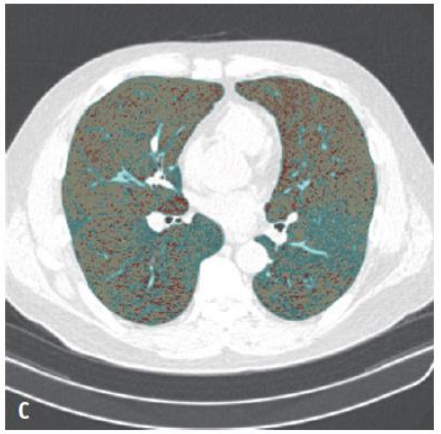
Sim DW, Choi S, Park HW, Kim SH, et al.
Ann Allergy Asthma Immunol 2024 Sep 6:S1081-1206(24)01502-3 (Online ahead of print)

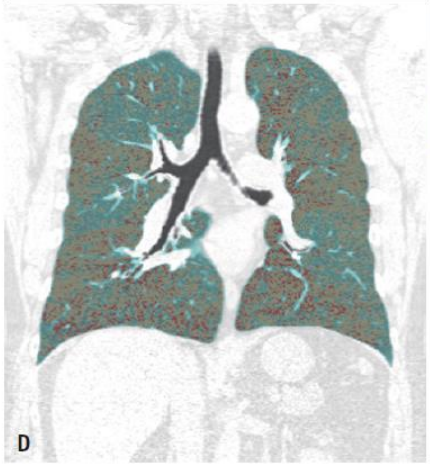
Possible roles of CT; *Prediction*

- **Assessment of treatment response in patients with severe asthma using visual & quantitative analysis of CT**





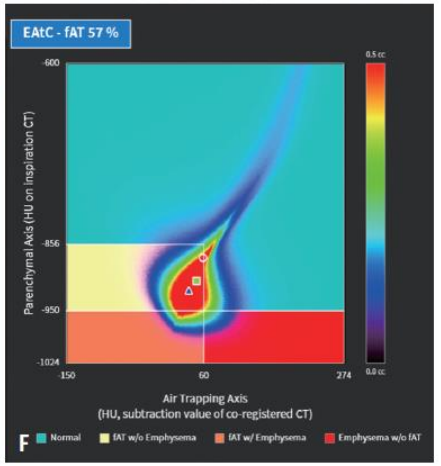




fAT 57 %

Regions	Normal (%)	fAT w/o Emp. (%)	fAT w/ Emp. (%)	Emp. w/o fAT (%)
Whole Lungs	38	48	9	5
Rt. Lung	41	48	6	5
Lt. Lung	35	48	12	5
RUL	45	47	5	3
RML	23	61	12	4
RLL	45	42	5	7
LUL	27	52	17	5
LLL	45	43	6	6

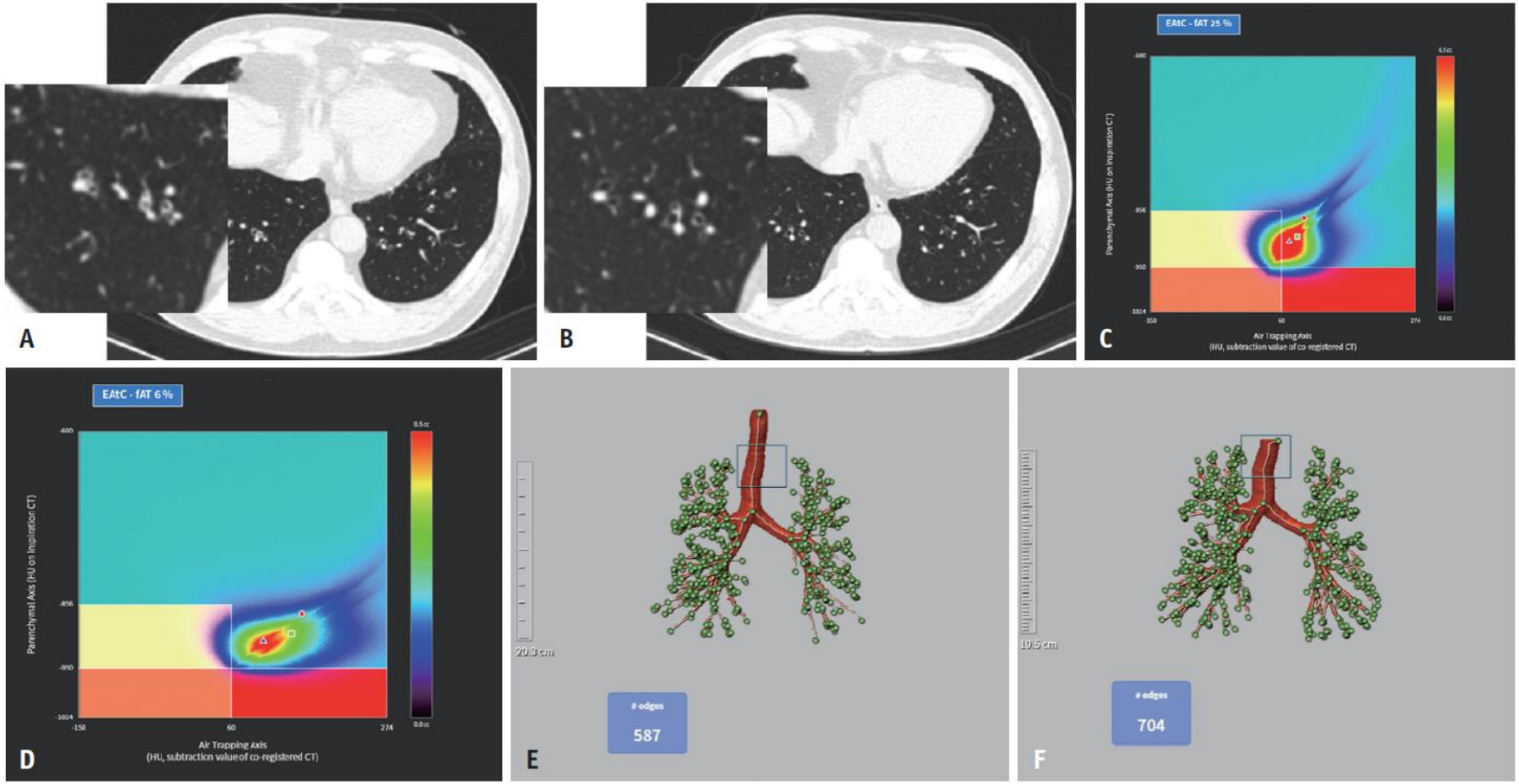
E



Korean J Radiol 2024;25:673-83

Possible roles of CT; *Prediction*

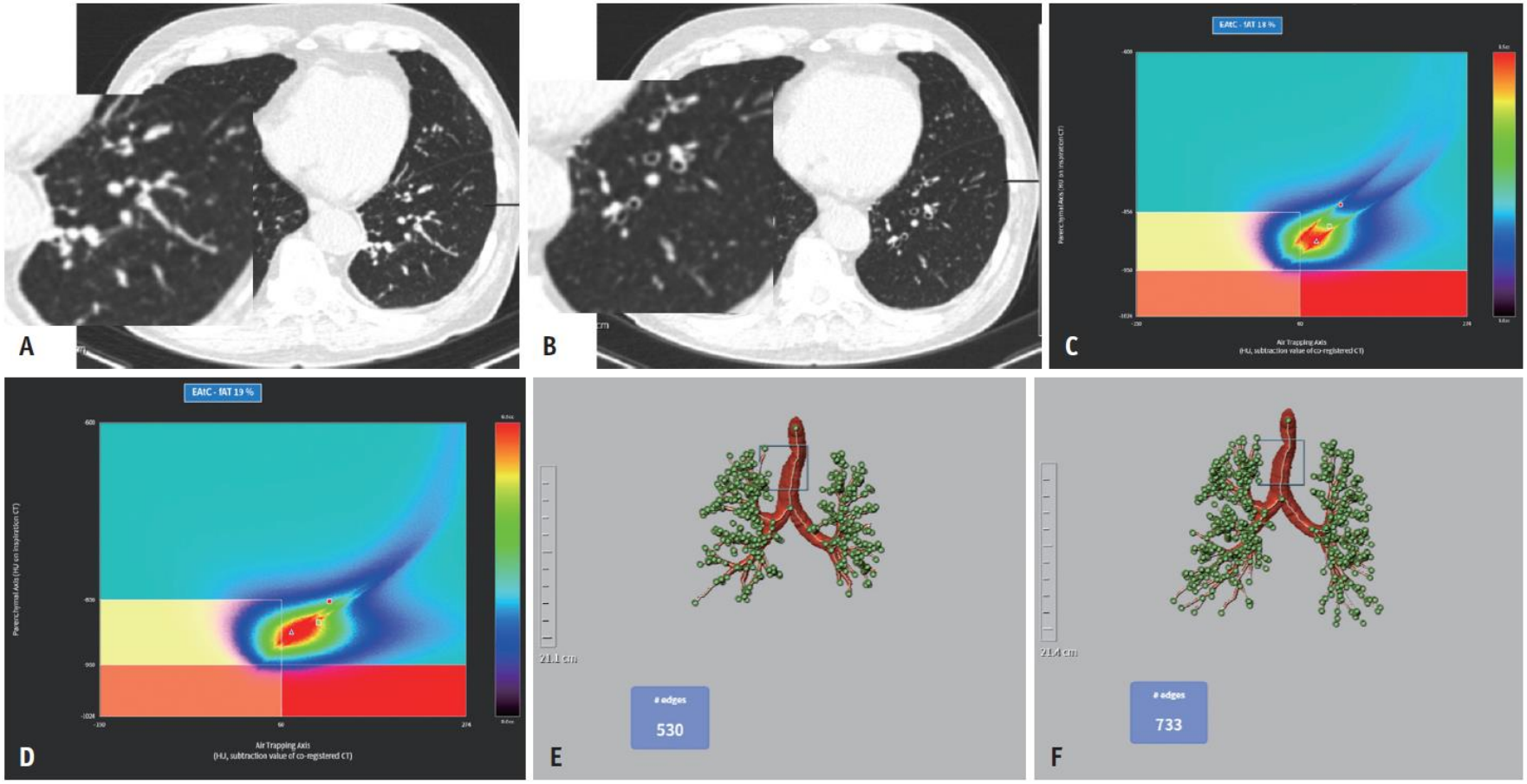
- **A patient with a greater improvement in FEV1**



Korean J Radiol 2024;25:673-83

Possible roles of CT; *Prediction*

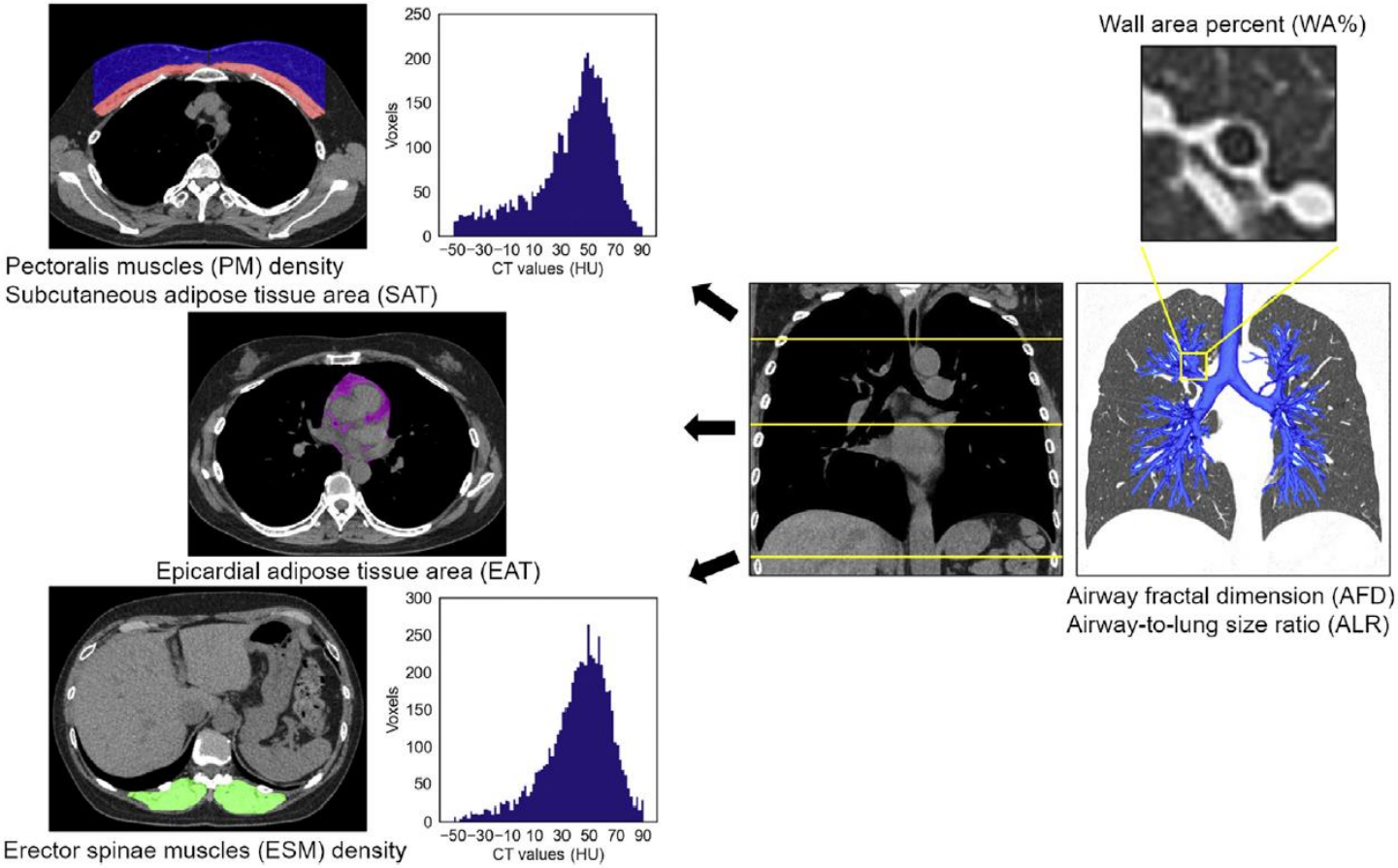
- **A patient with a minimal improvement in FEV1**



Korean J Radiol 2024;25:673-83

Possible roles of CT; *Other than airway*

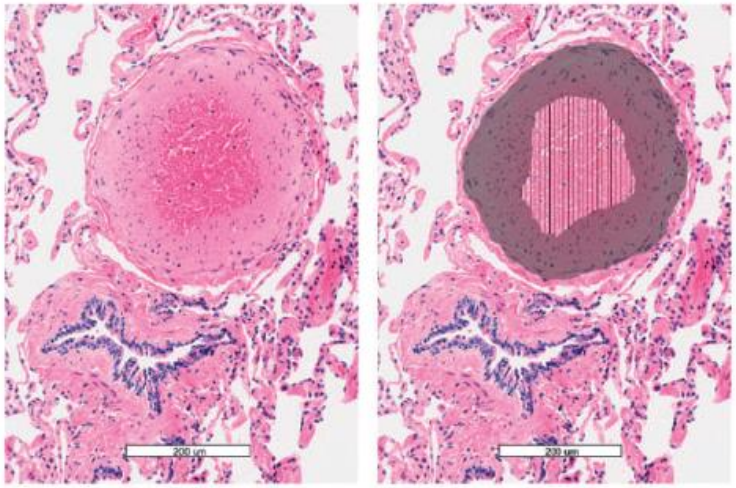
- **Lower skeletal muscle density & airway structure on CT in asthma**



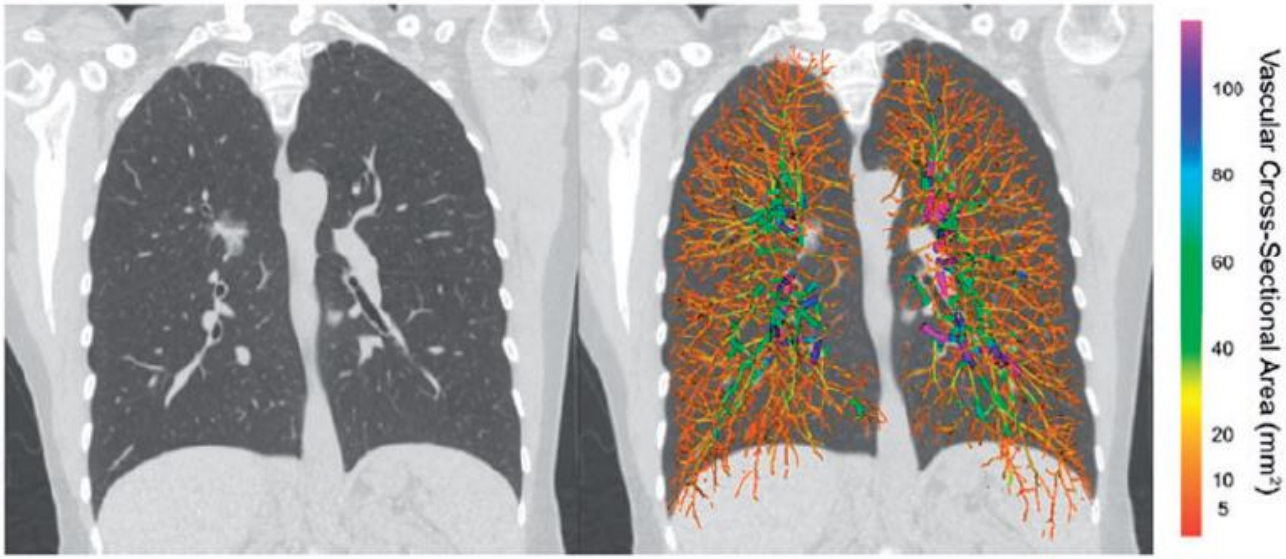
Ann Allergy Asthma Immunol 2024 Aug 22:S1081-1206(24)00527-1 (Online ahead of print)

Possible roles of CT; *Other than airway*

- **Vascular remodeling of the small pulmonary arteries & measures of vascular pruning on CT**



Small pulmonary artery



Volumetric reconstruction of the pulmonary vascular tree (vessels color-coded by size)

Pulm Circ 2021;11:20458940211061284

Possible roles of CT; *Other than airway*

- **Should we consider paranasal CT in severe patients with severe asthma?**

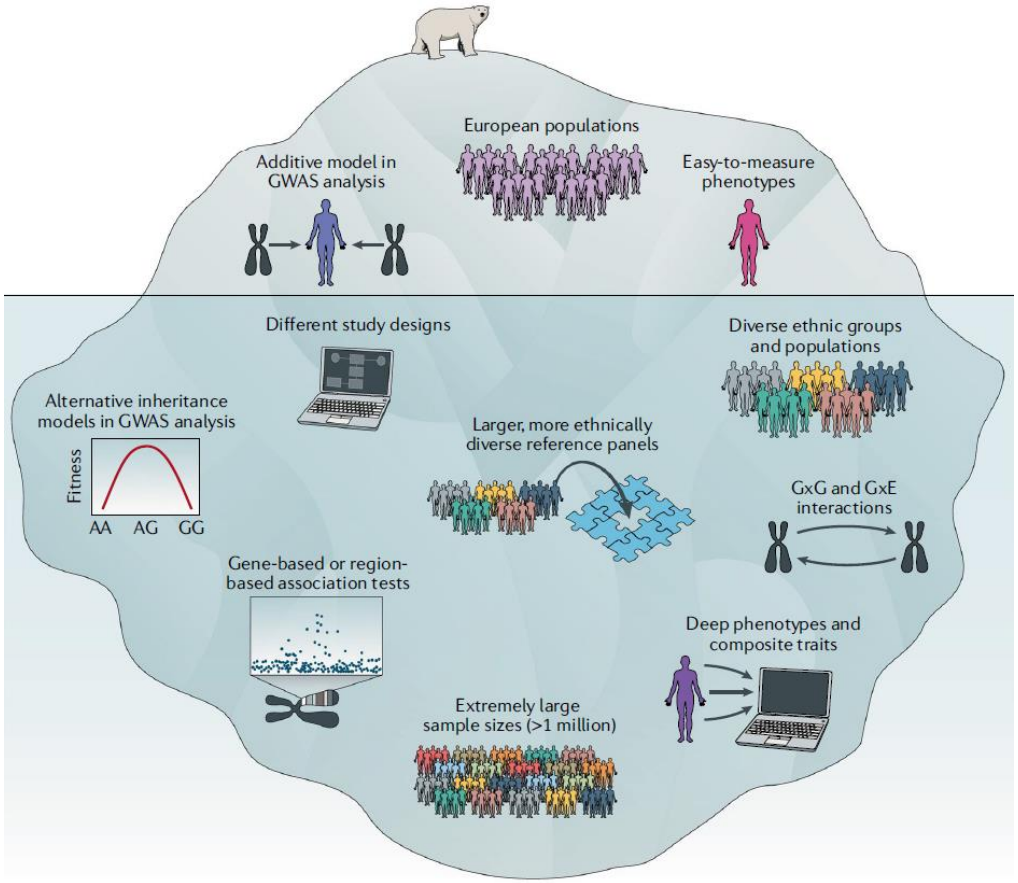
Findings in the paranasal computed tomography.

Sinus occupied n (%)	75 (73.0)
Mucous thickening n (%)	74 (70.5)
Nasal polyps n (%)	50 (46.7)
Ostiomeatal complex affectation n (%)	42 (39.0)
Nose affectation n (%)	35 (32.7)
Sinuses affected n ± SD	2.0 ± 1.6
Frontal n (%)	49 (45.8)
Maxillary n (%)	62 (57.9)
Sphenoid n (%)	44 (41.1)
Ethmoidal cells n (%)	63 (58.9)

Respir Med 2020:169:106013

Limitations

Standardization & Reproducibility



GWAS performed to date represent the tip of the iceberg

Nat Rev Genet 2019;20:467-84

Conclusions

- CT plays an important role in the management of severe asthma
- Better characterization or phenotyping of severe asthma based on CT will lead towards new treatment development, treatment strategies, & preventative care