2021 천식-COPD 연구회 공동 심포지엄

흉부 CT 소견으로 천식 환자 찾아내기

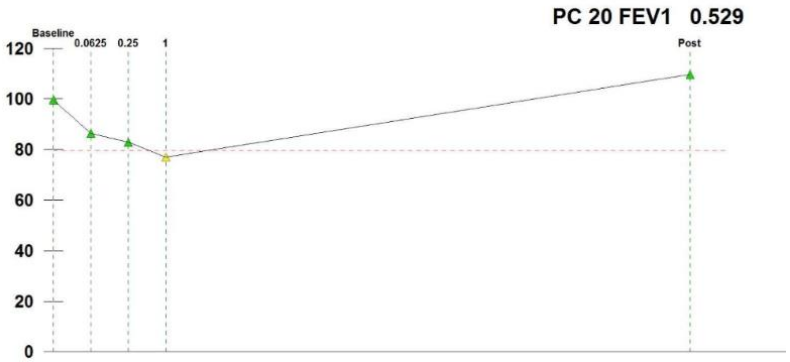
강남세브란스병원 박혜정

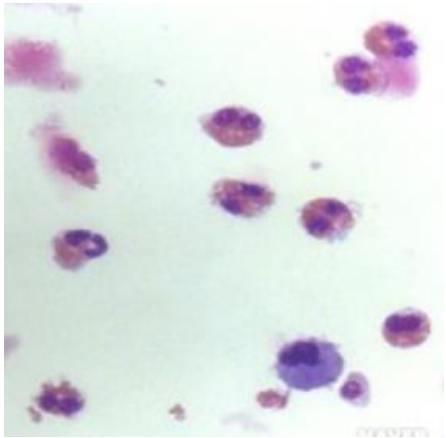
ASTHMA?

Technician: Nayoon Kim Diagnosis:

	Ref	Pre Meas	Baseline Meas	Level 1 Meas	Level 2 Meas	Level 3 Meas	Level 4 Meas	Level 5 Meas	Level 6 Meas	Level 7 Meas	Level 8 Meas	Post Meas
Dose				0.0625	0.25	1						
FVC Liters	3.89	4.64	4.96	4.51	4.49	4.38						4.47
% Ref		119	128	116	115	113						115
% Chg			7	-9	-10	-12						-10
Dose				0.0625	0.25	1						
FEV1 Liters	3.58	3.48	3.64	3.15	3.02	2.81						4.00
% Ref		97	101	88	84	78						112
% Chg			4	-13	-17	-23						10
Dose				0.0625	0.25	1						
FEF25-75%	3.96	2.86	2.89	1.78	2.03	1.83						4.30
% Ref		72	73	45	51	46						109
% Chg			1	-39	-30	-37						49
Dose				0.0625	0.25	1						
PEF L/sec	7.84	7.05	6.75	6.64	6.21	5.87						7.68
% Ref		90	86	85	79	75						98
% Chg			-4	-2	-8							14

PC 20 FEV1: 0.529 Provocholine %Chg FEV1 vs Dose (mg/ml)





Chest CT in Asthma

- Other pulmonary investigations: DLCO; CXR or high resolution chest CT

- Consider additional diagnostic investigations (if available and not already done): sputum induction to confirm inflammatory phenotype, high resolution chest CT, bronchoscopy to exclude unusual comorbidities or alternative diagnoses such as tracheobronchomalacia or sub-glottic stenosis; functional laryngoscopy for inducible laryngeal obstruction.

Consider additional investigations (if not already done): high resolution chest CT; induced sputum to confirm inflammatory phenotype, consider referral if available, including for diagnosis of alternative conditions.

➢ 천식에서 chest CT의 역할: 감별 진단, 동반질환 탐색 등

2020 GINA guildeline

Chest CT in Asthma

Box 5-4. Specialized investigations sometimes used in distinguishing asthma and COPD

	Asthma	COPD
Lung function tests		
DLCO	Normal (or slightly elevated).	Often reduced.
Arterial blood gases	Normal between exacerbations	May be chronically abnormal between exacerbations in more severe forms of COPD
Airway hyperresponsiveness (AHR)	Not useful on its own in distinguishing asthma from COPD, but higher levels of AHR favor asthma	
Imaging		
High resolution CT Scan	Usually normal but air trapping and increased bronchial wall thickness may be observed.	Low attenuation areas denoting either air trapping or emphysematous change can be quantitated; bronchial wall thickening and features of pulmonary hypertension may be seen.

- 천식에서 chest CT소견은 보통 **"정상 "**

2020 GINA guildeline

Abnormal chest CT in Asthma

Classification of abnormalities in chest CT

- **LA** (large, central airway, >2mm):

Tracheal, lobar, segmental, subsegmental bronchi

- **SA** (small, peripheral airway, <2mm)

Airways distal to the subsegmental bronchi

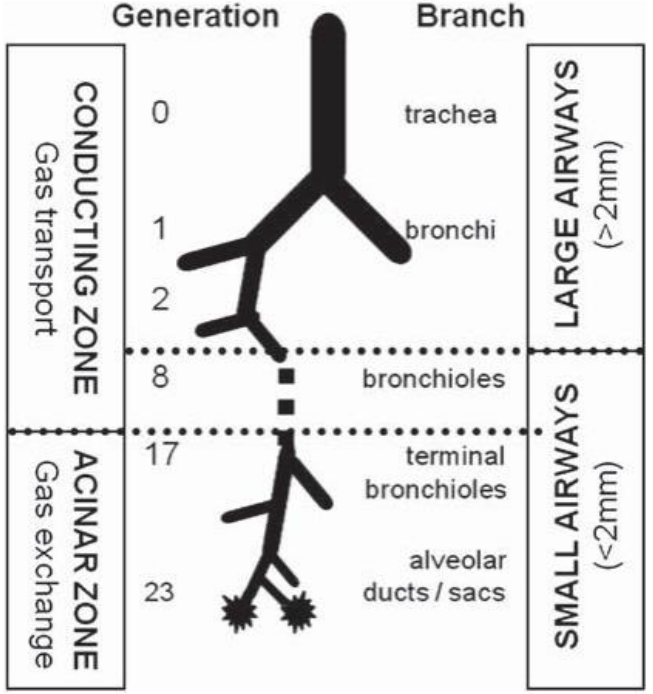


Figure 1. Airway dimensions and physiological compartments of the tracheobronchial tree.

Usmani et al.
Annals of Medicine
2012;44:146-56

Classification of abnormalities in chest CT

- **LA (large, central airway involvement)**

1) Wall thickening

➔ Causes: increased structural components
inflammatory infiltrate/edema

➔ Consequences: severity, airflow obstruction 악화

2) Luminal dilatation (Bronchiectasis)

➔ Causes: tissue destruction
lung volume 증가

➔ Consequences: severity 악화 (maybe fixed)

Niimi et al.
Clin Rev Allergy Immunol.
2004;27(1):45-58

Kim et al.
J Investig Allergol Clin Immunol
2018;28(5):312-20

Classification of abnormalities in chest CT

- **SA (small airway involvement)**

1) Decreased lung attenuation

➔ Causes: air trapping, aging, emphysema

➔ Consequences: airflow obstruction, severity 악화
hyperinflation

Niimi et al.
Clin Rev Allergy Immunol.
2004;27(1):45-58

Kim et al.
J Investig Allergol Clin Immunol
2018;28(5):312-20

Classification of abnormalities in chest CT

2) Mosaic attenuation

➔ Causes: Air trapping, hypoxic vasoconstriction
Infiltrative lung disease

➔ Consequences: Airflow obstruction, hyperinflation

3) Fixed lung area or attenuation at full-inspiration & expiration

➔ Causes: Air trapping

➔ Consequences: Airflow obstruction, hyperinflation

Niimi et al.
Clin Rev Allergy Immunol.
2004;27(1):45-58

Kim et al.
J Investig Allergol Clin Immunol
2018;28(5):312-20

ORIGINAL ARTICLE

Severe Asthma Phenotypes Classified by Site of Airway Involvement and Remodeling via Chest CT Scan

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*These authors contributed equally to this article.

J Investig Allergol Clin Immunol 2018; Vol. 28(5): 312-320
doi: 10.18176/jiaci.0265

- 91명의 중증 천식 환자의 흉부 CT를 후향적 분석
- 74 (81.3%) 환자가 흉부 CT 상에서 이상 소견 보임

Kim et al.
J Investig Allergol Clin Immunol 2018;28(5):312-20

Subtype of abnormalities in chest CT

- **LA** (large airway, central airway involvement):

Tracheal, lobar, segmental, subsegmental bronchi (large or medium airway remodeling type)

- **SA** (small airway involvement):

Airways distal to the subsegmental bronchi were involved or if air trapping or an emphysematous changes

- **NN** (Near normal type):

No remarkable abnormalities

Kim et al.
J Investig Allergol Clin Immunol 2018;28(5):312-20

Subtype of abnormalities in chest CT

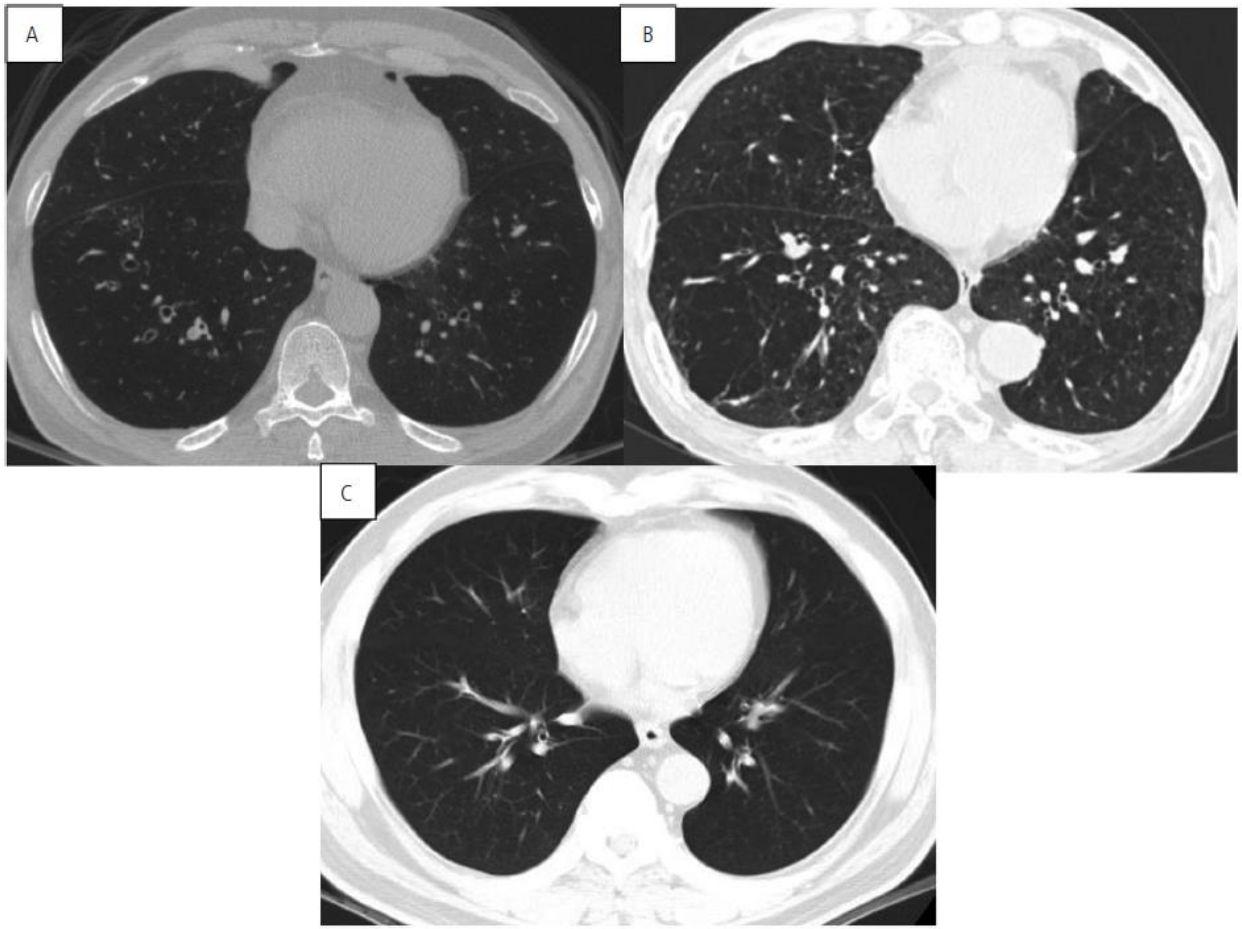


Figure 1. Representative computed tomography images of each phenotype. A, Large or medium airway remodeling. B, Small airway remodeling. C, Near-normal.

Kim et al.
J Investig Allergol Clin Immunol
2018;28(5):312-20

Table 2. Comparison of Clinical Characteristics for Individual Phenotypes[a]

	LA type (n=40)	SA type (n=6)	NN type (n=24)	*P* Value
Onset age, y	44.0 (40.0-51.0)	49.5 (32.0-65.0)	48.0 (39.0-56.5)	.640
Age at which CT was performed, y	58.0 (54.0-65.5)	69.0 (68.0-72.0)	61.0 (54.0-65.5)	.070
Disease duration, y	16.0 (12.0-21.0)	26.0 (16.0-34.0)	12.5 (8.0-20.0)	.078
BMI, kg/m^2	24.3 (3.8)	20.8 (3.7)	24.0 (2.7)	.656
Sex, No. (%)				.003
Male	13 (32.5%)[a]	6 (100.0%)[a]	14 (58.3%)	
Female	27 (67.5%)[a]	0 (0.0%)[a]	10 (41.7%)	
Smoking status, No. (%)				.003
Never smoked	29 (72.5%)[a]	0 (0.0%)[a,b]	15 (62.5%)[b]	
Ex- or current smoker	11 (27.5%)[a]	6 (100.0%)[a,b]	9 (37.5%)b	
Atopy, No. (%)	20 (52.6%)	2 (33.3%)	11 (47.8%)	.670
Sinusitis, No. (%)	29 (72.5%)	1 (20.0%)	14 (60.9%)	.061
Aspirin intolerance, No. (%)	2 (5.0%)	0 (0.0%)	3 (12.5%)	.411
Sputum eosinophil, %	16.2 (5.3-25.7)	7.8 (3.0-12.0)	6.7 (3.2-22.8)	.346
Sputum neutrophil, %	12.7 (1.7-19.7)	30.0 (12.0-36.3)	10.7 (2.4-23.8)	.544
PB eosinophil, %	6.2 (2.2-13.4)[c]	3.3 (1.5-6.3)	3.2 (2.1-5.1)[c]	.049
PB eosinophil count, cells/μL	430.0 (170.5-1176.5)[c]	234.0 (110.0-453.0)	213.0 (130.0-341.5)[c]	.032
Total serum IgE, IU/mL	193.5 (89.0-349.5)	226.0 (77.0-830.0)	165.0 (63.0-364.5)	.856
FEV1/FVC, %	69.5 (12.6)	49.7 (8.2)	73.9 (12.4)	.328
FEV1, % pred	64.9 (22.1)	49.8 (12.1)	71.0 (19.8)	.334
FVC, % pred	76.3 (19.1)	78.0 (10.6)	80.4 (15.2)	.357
Fixed obstruction, No. (%)[d]	14 (35.0%)[a]	6 (100.0%)[a,b]	6 (25.0%)[b]	.003
Controller medications, No.	4.0 (2.5-4.0)[a]	5.0 (5.0-5.0)[a,b]	3.0 (2.0-4.0)[b]	.004
Acute exacerbation in previous year, No.[e]	1.0 (0.0-2.0)	1.0 (1.0-3.0)	1.0 (0.0-1.0)	.196
Maintenance of oral corticosteroids, No. (%)	23 (57.5%)	5 (83.3%)[b]	7 (29.2%)[b]	.021

LA type: PB eosinophil ↑

SA type: Smoking history, fixed medication, OCS ↑

Kim et al.
J Investig Allergol Clin Immunol
2018;28(5):312-20

Subtype of abnormalities in chest CT

Table 1. Results of Multiple Linear Regression Analysis of Clinical Indices and Computed Tomography Findings[a]

Dependent Variable	Independent Variable	Coefficient (β)	SE	*P* Value	R^2
BT severity score	PB eosinophil, cells/μL	0.001	0.0002	.012	0.112
MP extent score	Sputum eosinophil, %	0.030	0.013	.022	0.090
BE extent score	Sex: male (ref) vs female	0.953	0.320	.004	0.137
	FEV_1, % predicted	–0.023	0.008	.004	
BE severity score	Sex: male (ref) vs female	0.726	0.272	.010	0.103
Emphysema index, %	Smoker: never (ref) vs current or previous	7.845	3.303	.023	0.426
	FEV_1/FVC, %	–0.375	0.113	.002	

Abbreviations: BE, bronchiectasis; BT, bronchial wall thickening; FEV_1, first second of forced expiratory volume; FVC, forced vital capacity; MP, mucus plugging; PB, peripheral blood; ref, reference group; SE, standard error.
[a]Age, sex, and variables for which $P<.1$ in simple linear regression models were adjusted in the multiple linear regression analysis.

Kim et al.
J Investig Allergol Clin Immunol 2018;28(5):312-20

CONTENTS

Measurement of airway wall thickness (WA)

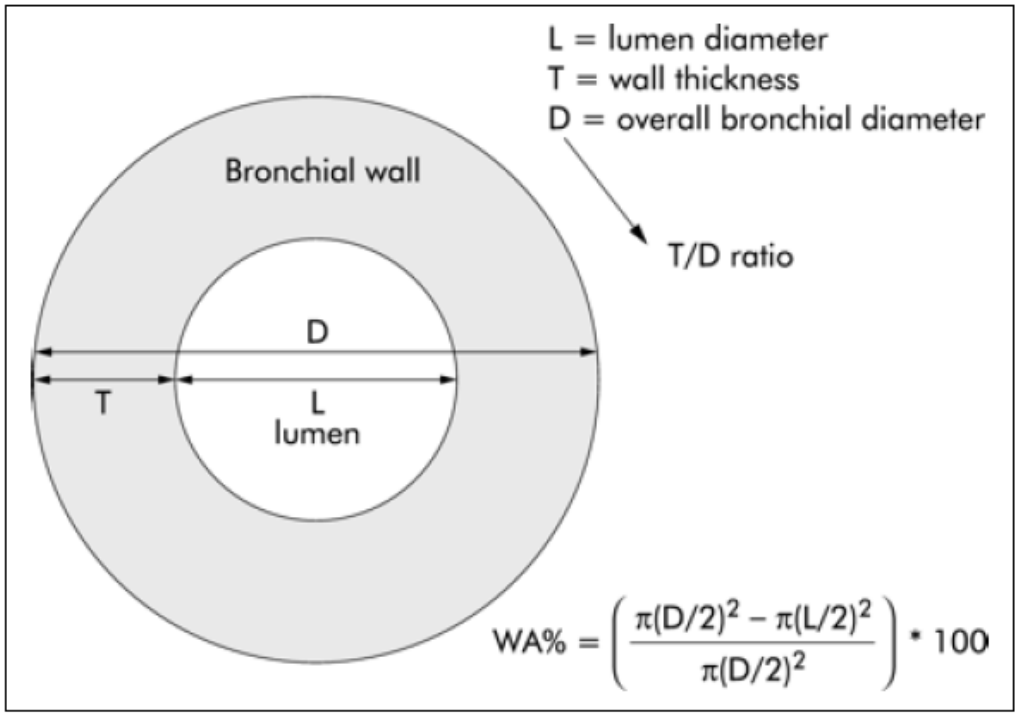
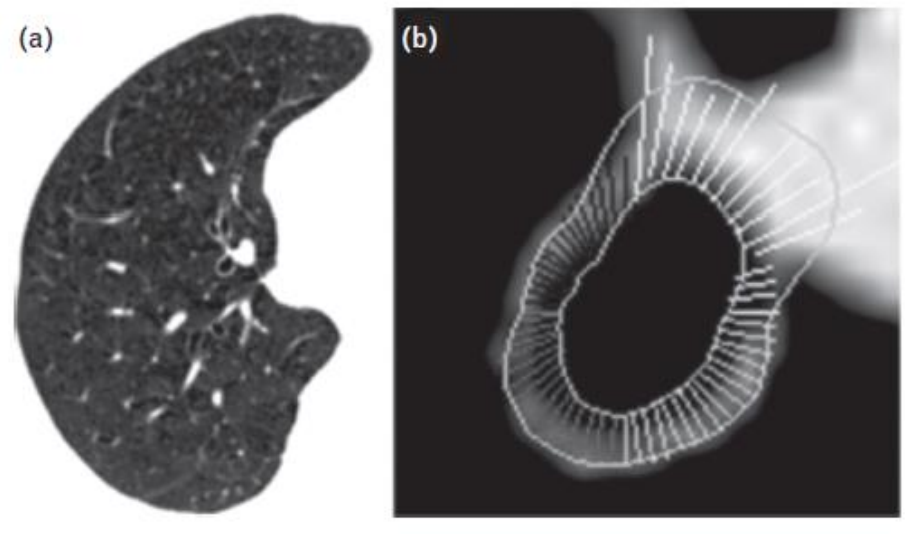
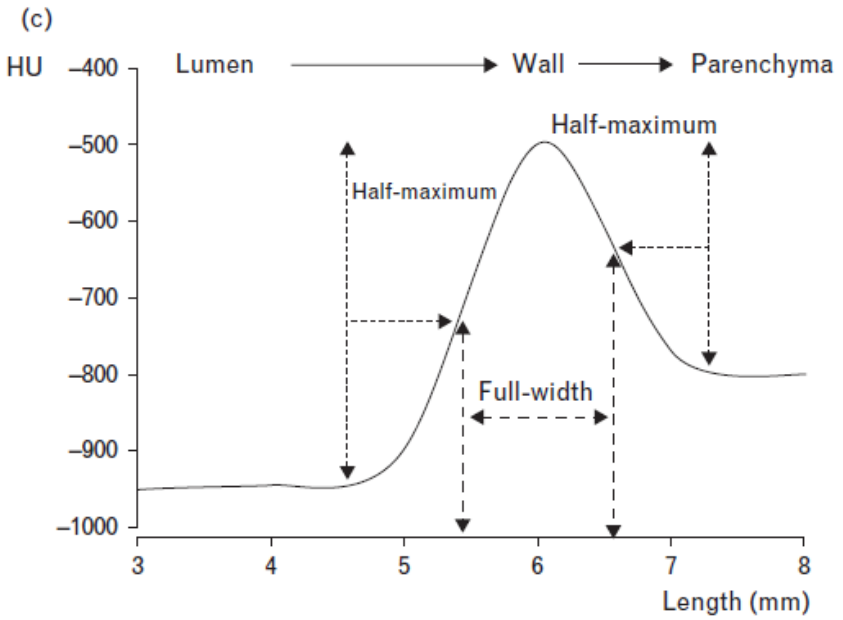


Figure 1. Measurement of bronchial and lumen diameter with calculation of WA% and T/D ratio

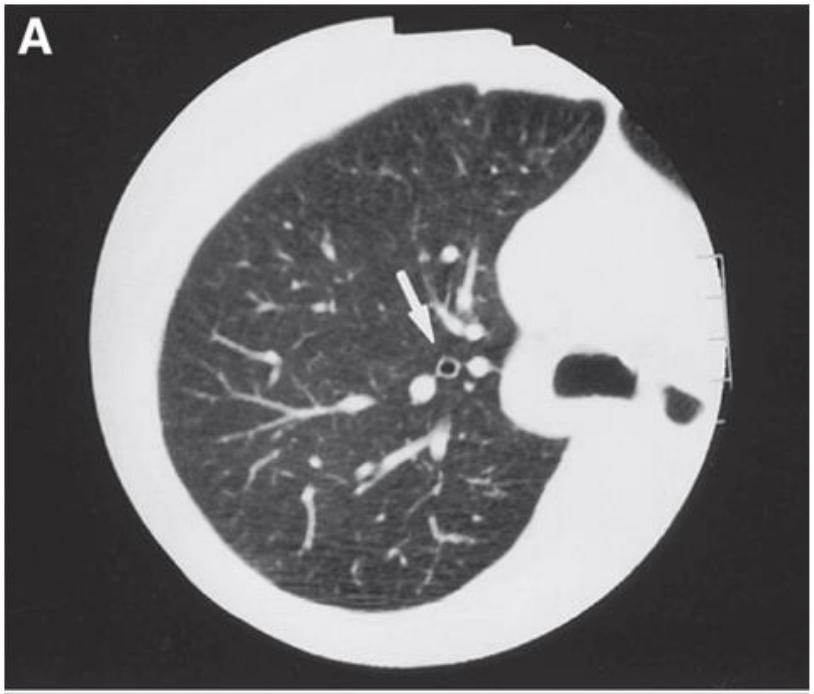
Park et al.
Tuberc Respir Dis
2005;59(6):591-9

Quantitative assessment of airway wall thickness





De Jong et al.
Eur Respir J
2005;26:140-52

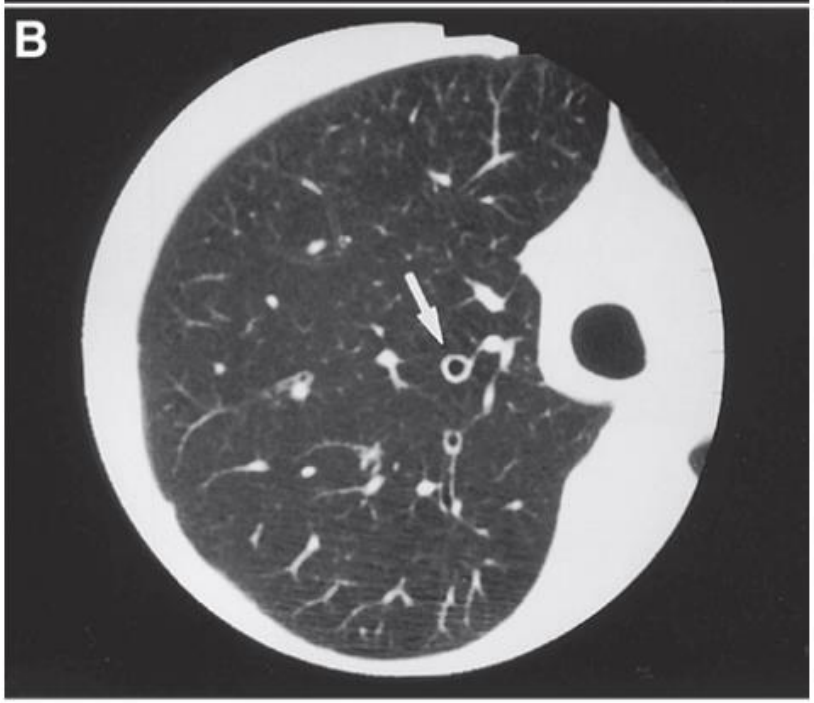


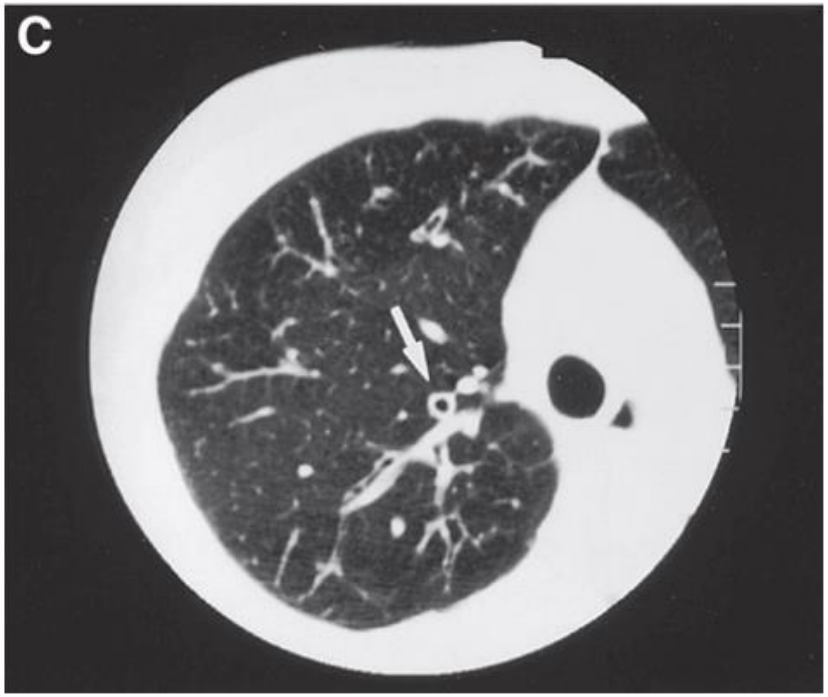
◀ Control subjects

◣ Mild asthma

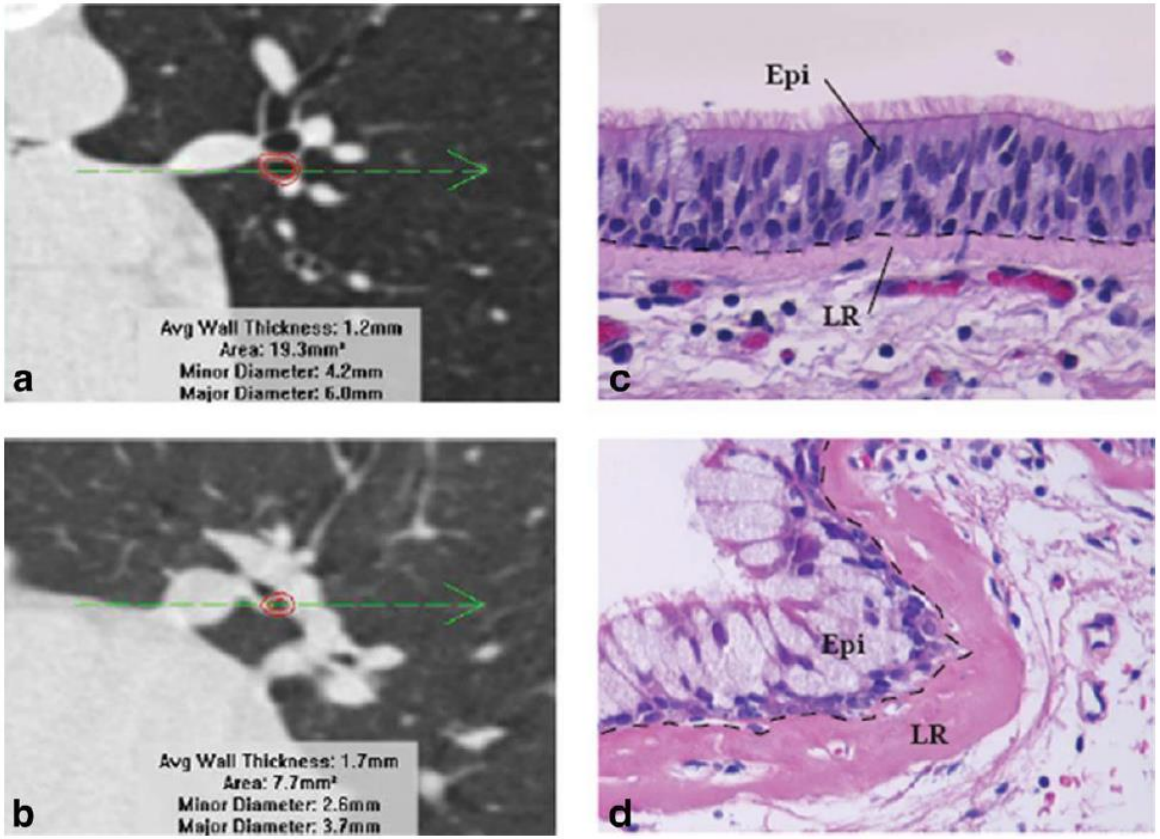
▼ Severe asthma

Niimi et al.
Clin Rev Allergy Immunol.
2004;27(1):45-58





Airway wall thickness ← thickened LR



- Thickened lamina reticularis (LR)

Figure 1. A–D: CT images and bronchial biopsy specimens from healthy subjects (A,C) and patients with severe asthma (B,D). The epithelial layer (Epi), lamina reticularis (LR), and the basement membrane (dashed line) are indicated (C,D). In the normal subjects, note the thin airway wall on CT (A) and the normal thickness LR (C). In the severe asthma patients, the airway wall was thickened on CT (B) and the LR thickened on histology (D). Reprinted with permission from Aysola et al (13).

Aysola et al.
J Magn Reson Imaging
2010;32:1379-87

Airway wall thickness

Quantitative Assessment of Airway Remodeling Using High-Resolution CT*

Yasutaka Nakano, MD, PhD; Nestor L. Müller, MD PhD; Gregory G. King, MD, PhD; Akio Niimi, MD, PhD; Steven E. Kalloger, BSc; Michiaki Mishima, MD, PhD; and Peter D. Paré, MD

- 다양한 천식 환자 102명 포함

➔ 천식 환자가 CT에서 관찰되는 **airway wall area** 가 넓음

Table 1—*Large Airway Dimensions in Asthma Measured Using HRCT

Subject Variables	Control Subjects (n = 28)	Asthmatic Subjects: Mild Persistent (n = 13)	Asthmatic Subjects: Moderate Persistent (n = 39)	Asthmatic Subjects: Severe Persistent (n = 22)
Age	54 ± 14	46 ± 21	51 ± 17	51 ± 12
FEV_1, % predicted	108 ± 17	93 ± 14†	81 ± 20†‡	46 ± 19†‡§
Ai, mm^2	15 ± 6	14 ± 7	16 ± 6	16 ± 8
WA%	55 ± 7	64 ± 9†	63 ± 6†	67 ± 9†§
Aaw, mm^2	18 ± 4	24 ± 6†	26 ± 8†	31 ± 8†‡§

*Values given as mean ± SD. Data reprinted with permission from Niimi et al.[10]

†$p < 0.05$ compared to control.

‡$p < 0.05$ compared to subjects with mild persistent asthma.

§$p < 0.05$ compared to moderate persistent asthma.

Ai: airway luminal area

WA: Aaw/[Aaw+Ai] x 100

Aaw: airway wall area

Nakano et al. Chest 2002;122:271S-275S

Airway wall thickness - 중증도

- WA/BSA가 천식 환자에서 증가

➔ 중증도 올라갈수록 증가

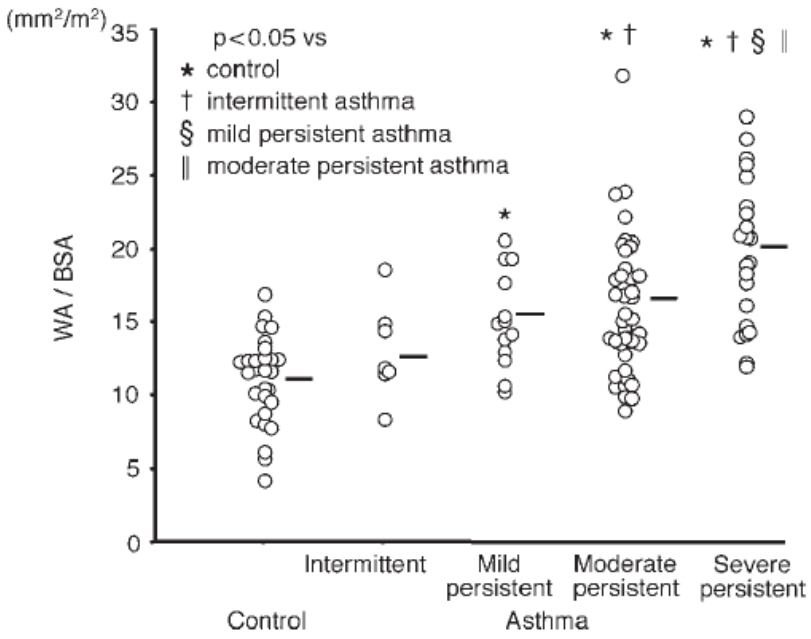


Fig. 2. The distribution of airway wall area (WA)/body surface area (BSA) in the control and four asthmatic groups. Bars represent means. The difference among the groups was significant by analysis of variance (ANOVA) ($p < 0.001$). From ref. *30*.

Niimi et al.
Am J Respir Crit Care Med
2000;162:1518-23

Airway wall thickness - sputum neutrophil

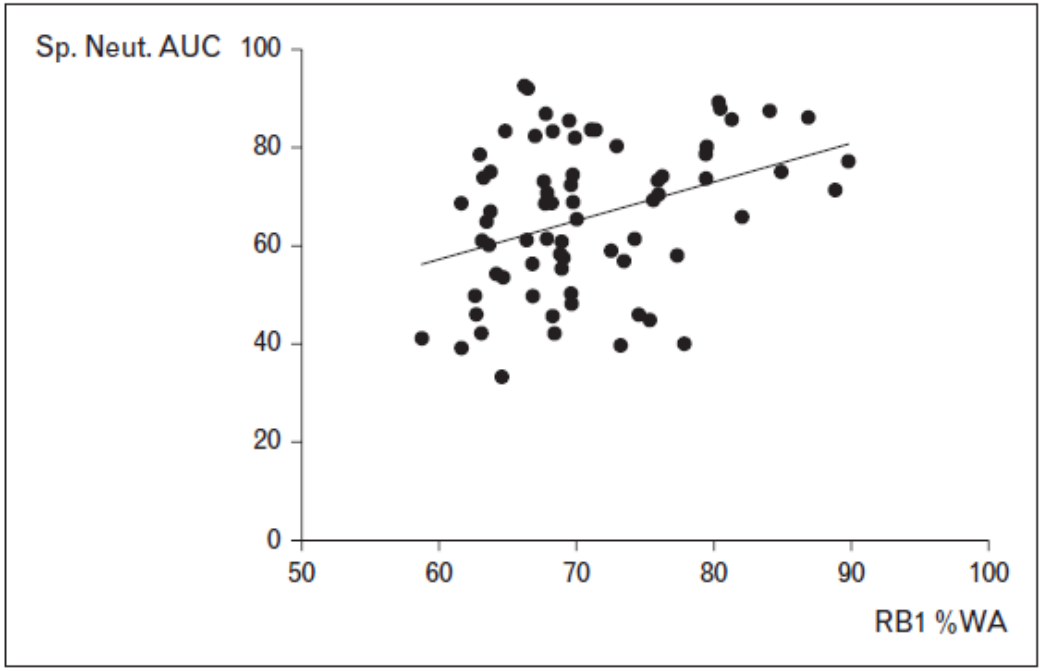


FIGURE 2. Correlation between right upper lobe apical segmental bronchus (RB1) percentage wall area (%WA) and sputum neutrophil area under the curve (Sp. Neut. AUC%) in patients with severe asthma ($r = 0.36$, $P < 0.005$) [14▪▪].

Walker et al.
Curr Opin Pulm Med
2012;18:42-7

Airway wall thickness - ECP

- Low ECP group이 WA/BSA 높음

Table 3
Characteristics of Patients With Asthma Who Show Low or High Serum ECP Titers During Acute Exacerbation

	Low ECP group (Serum ECP <16 μg/L)	High ECP group (≥16 μg/L)	*p* values
Number of subjects	37	54	
Male (%)	15 (41)	33 (61)	0.058
Age (yr)	54 ± 15	41 ± 16	<0.0001
Age at the disease onset (yr)	41 ± 21	35 ± 19	0.19
Disease duration (year)	14 ± 20	6 ± 9	0.01
Atopy (%)	23 (62)	38 (70)	0.5
Smoker (%)	3 (8)	9 (13)	0.35
Disease severity (step), 1:2:3:4	0/14/15/8	1/12/30/11	0.31
Presence of upper respiratory infection (%)	5 (14)	5 (9)	0.73
Usage of inhaled steroid (%)	9 (24)	13 (24)	>0.99
Usage of sustained-release theophylline (%)	16 (43)	24 (44)	>0.99
PEF (% of personal best)	66 ± 19	62 ± 23	0.65
FEV_1 (% predicted)	79 ± 24	75 ± 24	0.52
Log IgE (U/mL)	2.1 ± 0.6	2.5 ± 0.6	0.004
Blood eosinophils (10^6/L)	435 ± 358	797 ± 620	0.001
WA/BSA at stable condition (mm^2/m^2)[a]	15.2 (6.4–25.8)	12.6 (7.6–21.9)	0.035

[a] Examined in 18 patients from the low ECP group and in 23 from the high ECP group.
From ref. 41.

Niimi et al.
Clin Rev Allergy Immunol.
2004;27(1):45-58

Airway wall thickness – airway reactivity

- WA/BSA가 높을수록, 반응성 (airway reactivity) 낮음 (stiff?)
- ICS 사용력과 무관

SRrs: the index of airway reactivity

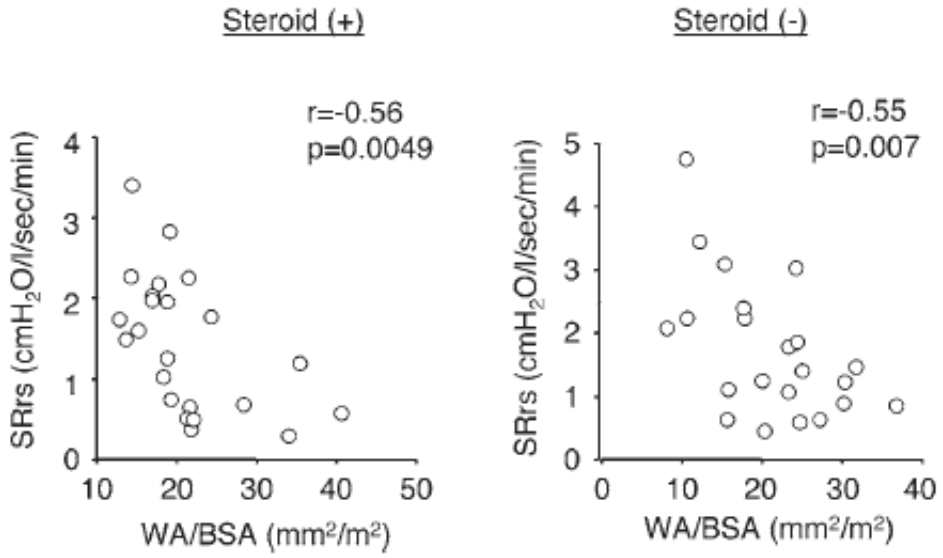


Fig. 3. Relationship between airway reactivity and airway wall thickness in stable patients with asthma with (n = 23) and without (n = 22) inhaled corticosteroid treatment. SRrs, the index of airway reactivity, was negatively correlated with WA/BSA in both groups. From ref. *43*.

Niimi et al.
Clin Rev Allergy Immunol.
2004;27(1):45-58

Airway wall thickness – 천식 기간

- WA/BSA는 천식 기간 길수록 높음
- 천식 기간 길수록 WA/BSA의 치료 후 호전 미약

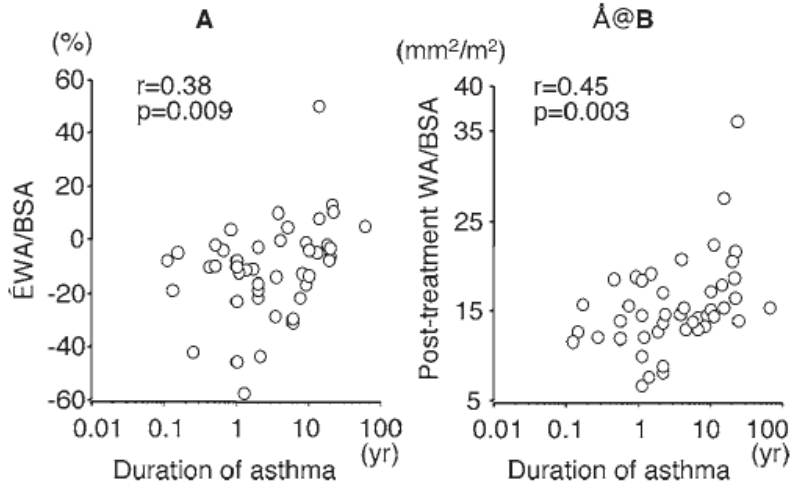


Fig. 5. Relations of the duration of asthma at entry to (**A**) the percent change in WA/BSA in response to treatment and (**B**) posttreatment WA/BSA. In patients with more prolonged disease, reduction in airway wall thickness is less (**A**), and airway wall thickening remaining after treatment is more prominent (**B**). From ref. *53*.

Niimi et al.
Clin Rev Allergy Immunol.
2004;27(1):45-58

Airway wall thickness – 치료 후 호전

- ICS 치료 후 호전되는 airway wall thickening

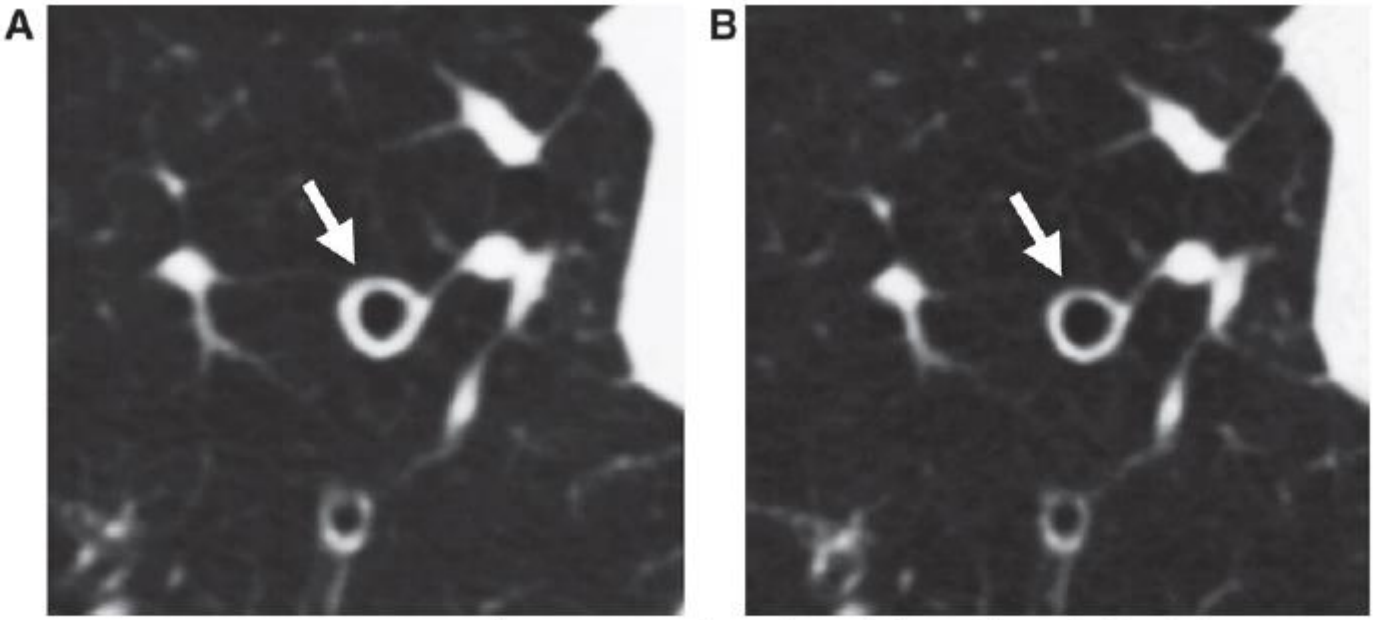


Fig. 4. Representative CT images of a patient with asthma before (**A**) and after (**B**) treatment with beclomethasone. Views of the apical bronchus of the right upper lobe are indicated by arrows. Airway levels are identical as confirmed by anatomic landmarks such as blood vessels and bronchi. From ref. *53*.

Niimi et al.
Clin Rev Allergy Immunol.
2004;27(1):45-58

CONTENTS

Bronchial dilatation and bronchiectasis

- Bronchial dilatation and bronchiectasis

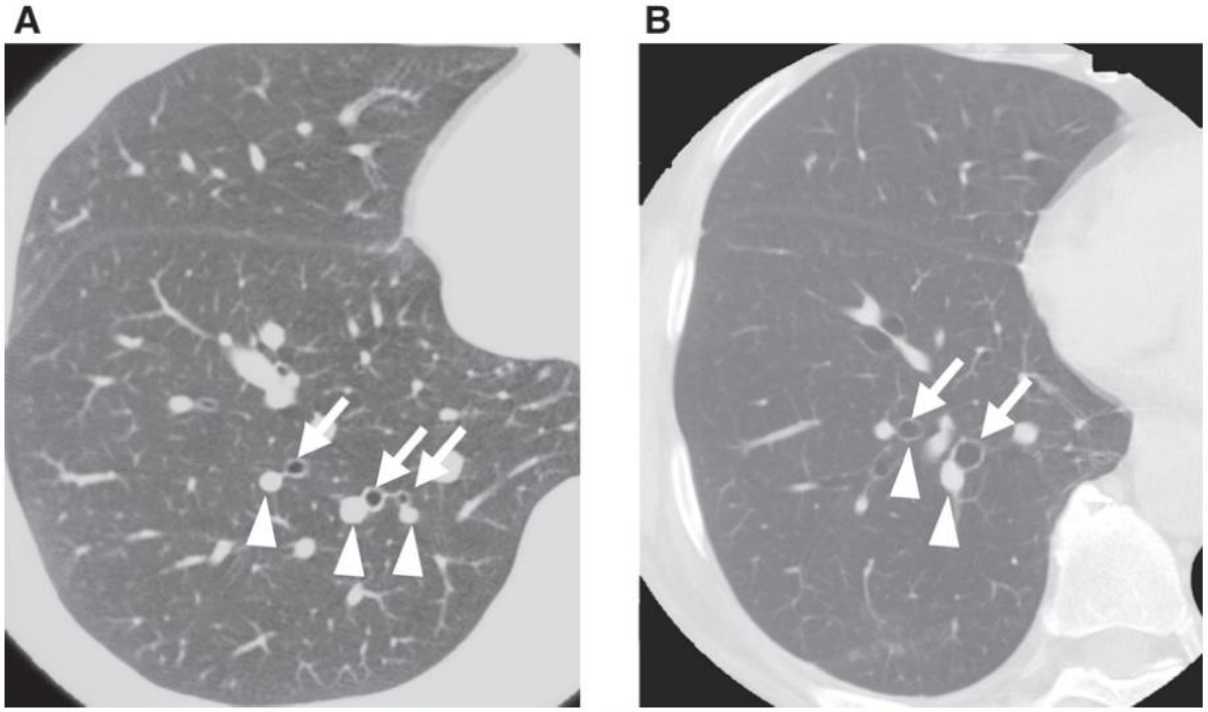


Fig. 6. Representative HRCT images (right lower lobe) of (**A**) a control subject and (**B**) a patient with asthma. Luminal areas of bronchi (arrow) are greater than the cross-section of the adjacent pulmonary artery (arrowhead) in the patient with asthma, but not in the control subject. From ref. *55*.

Niimi et al.
Clin Rev Allergy Immunol.
2004;27(1):45-58

Severe asthma and bronchiectasis

Marta García-Clemente, PhD[a], Ana Isabel Enríquez-Rodríguez, MD[a], Marta Iscar-Urrutia, PhD[a], Beatriz Escobar-Mallada, MD[b], Miguel Arias-Guillén, PhD[a], Francisco Julián López-González, PhD[a], Claudia Madrid-Carbajal, MD[a], Liliana Pérez-Martínez, MD[a], and Teresa Gonzalez-Budiño, MD[a]

- Among 108 **severe asthma** patients

Abnormality	Prevalence
Abnormality	55%
Bronchiectasis	**35%**
Bronchial wall thickening	33%
Emphysema	7%
Atelectasis area	6%
Mosaic attenuation due to air trapping	4%
Tree in bud	2%

Garcia-Clemente et al. J Asthma 2020;57(5):505-9

Table 2. Baseline clinical, functional and analytic characteristics of subjects with bronchiectasis and normal HRCT.

Parameter	Severe asthma with normal HRCT ($N = 49$)	Severe asthma with HRCT with bronchiectasis ($N = 38$)	p
Age (years)	47.5 ± 15.8	58.6 ± 12.6	0.001
Sex	24 male/25 female	19 male/19 female	0.925
Smoking status	12 smokers (24.4%)	9 smokers (23.6)	0.832
Time since disease onset (years)	20.9 ± 14.1	27.5 ± 15.9	0.048
Exacerbations in the previous year	1.3 ± 1.4	2.5 ± 1.7	0.071
FVC (m ± SD)	89 ± 18.9	80.7 ± 15.1	0.031
FEV1 (m ± SD)	78.9 ± 22.5	66.8 ± 18.4	0.008
FEV1/FVC (m ± SD)	70.2 ± 11.3	62.9 ± 10.6	0.003
Chronic airflow limitation	22/49	31/38	0.001
Long-acting beta-2 agonist	44/49	38/38	0.092
ICSs	46/49	38/38	0.309
ICS dose	731.3 ± 216.3	991.6 ± 258.3	0.248
Anticholinergics	11/49	11/38	0.348
Leukotriene receptor antagonist	10/49	6/38	0.551
Macrolides	6/49	9/38	0.265
Oral corticosteroids	8/49	8/38	0.604
Omalizumab	7/49	12/38	0.049
Cycles of antibiotic therapy in the previous year	1.2 ± 1.1	1.9 ± 1.8	0.006
Chronic rhinosinusitis	27/49	23/38	0.816
Gastroesophageal reflux disease	9/49	6/38	0.243
Nasal polyps	9/49	12/38	0.200
Hospitalized in the previous year	14/49	13/38	0.223
Number of hospitalizations in the previous year	0.26 ± 0.53	0.73 ± 1.11	0.019
Total IgE (UI/mL)	395.8 ± 310.2	298.3 ± 245.3	0.189
Eosinophils in peripheral plasma/μL (m ± SD)	360 ± 230	410 ± 290	0.165

Garcia-Clemente et al.
J Asthma
2020;57(5):505-9

Should we consider paranasal and chest computed tomography in severe asthma patients?

E. Zamarron [a,*], D. Romero [a], J. Fernández-Lahera [a], C. Villasante [a], I. Pinilla [b], P. Barranco [c], J. Dominguez-Ortega [c], R. Álvarez-Sala Walther R [a,d]

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[d] School of Medicine, Universidad Autónoma de Madrid, Madrid, Spain

- 161 severe asthma

Table 2
Findings in chest computed tomography.

Bronchiectasis	95 (60.5)
1 lobe n (%)	20 (12.2)
2 lobes n (%)	28 (17.1)
>2 lobes n (%)	44 (26.8)
Central n (%)	19 (11.6)
Atelectasis n (%)	46 (28.0)
Small airway n (%)	29 (17.7)
Air trapping n (%)	27 (16.5)
Pulmonary infiltrates n (%)	19 (11.6)
Emphysema n (%)	17 (10.4)

Zamarron et al. Respir Med 2020;169:106013

Bronchial dilatation and bronchiectasis

Table 4
Clinical data of patients with bronchiectasis.

BRONCHIECTASIS	YES	NONE	p
Total n (%)	95 (60.5)	62 (39.5)	–
Sex-females n (%)	52 (54.7)	43 (66.2)	0.100
Age, (SD)	58 ± 18	53 ± 16	0.015
Blood eosinophils/μL, x ± SD	350.8 ± 287.3	356.0 ± 293.5	0.218
Total serum IgE, $\bar{x}$ ± SD	318.4 ± 642.5	408.4 ± 1101.5	0.439
Exacerbations/y, $\bar{x}$ ± SD	2.7 ± 1.7	2.3 ± 1.9	0.271
Hospitalizations $\bar{x}$ ± SD	0.3 ± 0.5	0.2 ± 0.4	0.976
FVC, $\bar{x}$ ± SD	90.0 ± 21.5	98.1 ± 18.3	0.017
FEV_1, $\bar{x}$ ± SD	68.9 ± 20.2	78.2 ± 25.2	0.028
CT infiltrates n (%)	12 (18.5)	3 (4.6)	0.013
Small airway n (%)	19 (29.2)	5 (7.7)	0.002
Air trapping n (%)	16 (24.6)	4 (6.2)	0.006
Nasal polyps n (%)	17 (42.5)	25 (52.1)	0.399
Mucous thickening n (%)	31 (75.6)	32 (71.1)	0.808
Pulmonary rehabilitation n (%)	13 (20.0)	4 (6.4)	0.042

$p < 0.05$. AERD, Aspirin-exacerbated respiratory disease; IgE, immunoglobulin E; FVC, forced vital capacity; FEV_1, forced expiratory volume in 1 s; CT, computed tomography.

Zamarron et al. Respir Med 2020;169:106013

ORIGINAL ARTICLE

WILEY

Investigation of bronchiectasis in severe uncontrolled asthma

Katerina Dimakou[1] | Anna Gousiou[2] | Michail Toumbis[3] | Maria Kaponi[1] | Serafeim Chrysikos[1] | Loukas Thanos[4] | Christina Triantafillidou[3]

- 40명의 severe uncontrolled asthma

TABLE 1 Demographic data and patients' characteristics (n = 40)

Male/Female	12/28
Age (years, mean ± SD)	57.9 ± 12.4 (range 30–83)
Smokers/nonsmokers/ex-smokers	6/32/2
Bronchiectasis in HRCT (yes/no)	27/13
Sputum culture (n = 40)	
Normal flora/pathogens	31 (77.5%)/ 9 (22.5%)
P. aeruginosa	1
P. aeruginosa+other pathogen	5
Other pathogen[a]	3

Dimakou et al. Clin Respir J 2018;12:1212-8

Bronchial dilatation and bronchiectasis

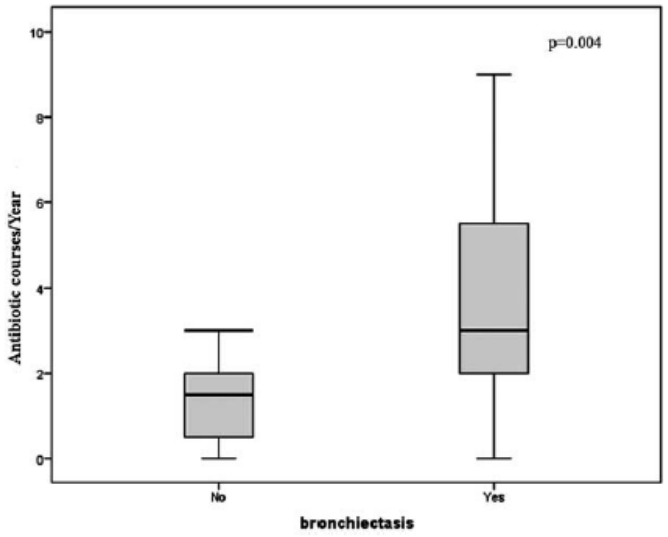


FIGURE 1 Patients with bronchiectasis consumed more antibiotics expressed as antibiotic courses per year in comparison with nonbronchiectasis patients (3.56 ± 2.3 vs 1.46±, $Z = 2.8$)

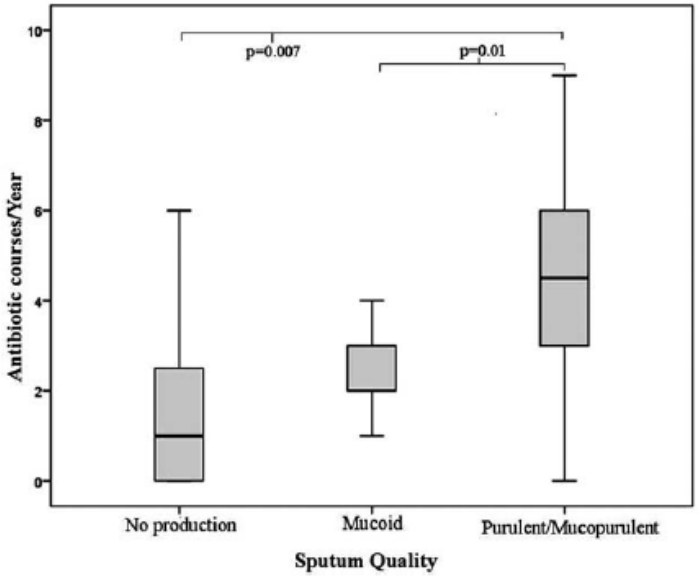


FIGURE 4 Patients with mucopurulent or purulent sputum consumed more antibiotics during the last year than patients with production of mucoid sputum or no expectoration

Debray et al.
Eur Respir J
2017;49:1601565

Mucus plug

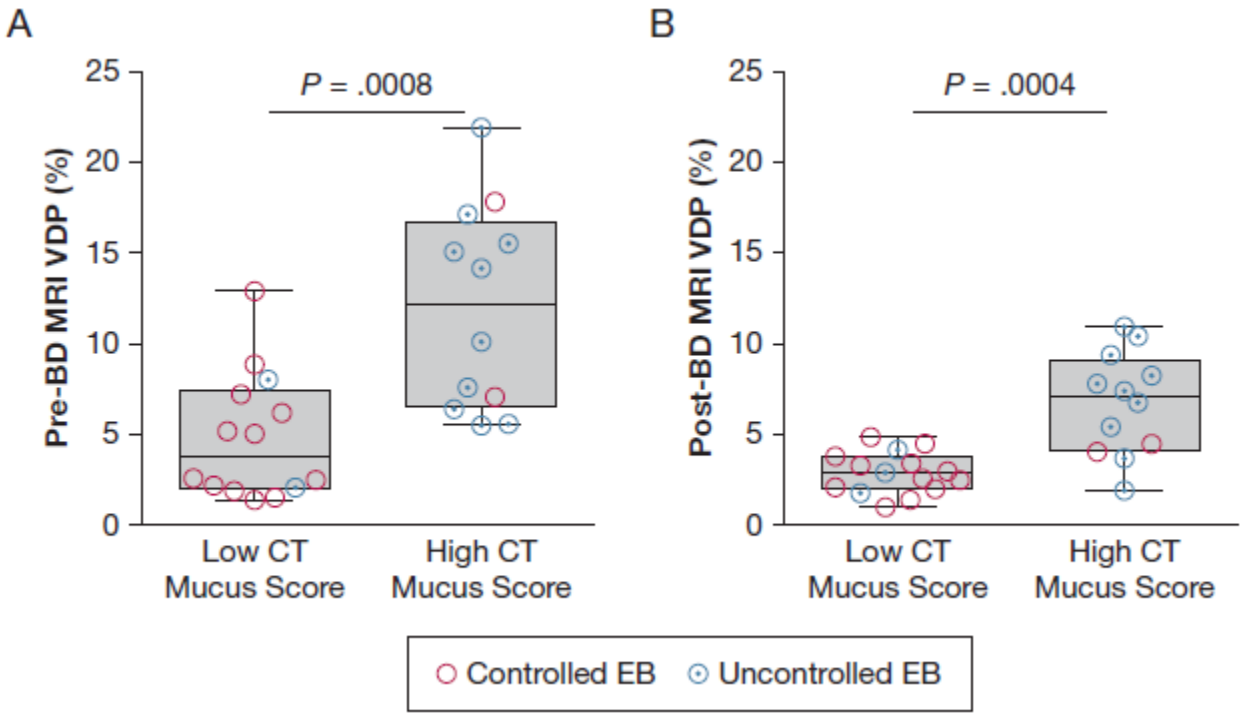
- 27 severe asthma
- Mucus score (1개의 segment당 mucs 존재 여부의 합, 0-20)
- Sputum eosinophil 존재시 EB로 분류

TABLE 2] Whole Lung and Lobar CT Mucus Plug Scores and MRI Ventilation Defect Percentages

Measurement	All (N = 27)	Uncontrolled EB (n = 13)	Controlled EB (n = 14)	Significance of Difference (*P* Value)[a]
CT mucus plug score				
Post-BD whole lung[b]	3.0 (0.0-17.0)	11.0 (2.5-15.5)	0.0 (0.0-17.0)	**.0006**
Post-BD RUL[b]	0.0 (0.0-3.0)	1.0 (0.0-3.0)	0.0 (0.0-2.0)	**.01**
Post-BD RML[b]	0.5 (0.0-2.0)	1.0 (0.0-2.0)	0.0 (0.0-2.0)	**.02**
Post-BD RLL[b]	1.0 (0.0-5.0)	2.0 (0.0-5.0)	0.0 (0.0-4.0)	**.003**
Post-BD LUL[b]	0.5 (0.0-5.0)	3.0 (0.5-5.0)	0.0 (0.0-5.0)	**< .0001**
Post-BD LLL[b]	0.5 (0.0-5.0)	3.0 (0.0-5.0)	0.0 (0.0-5.0)	**.006**

Svenningsen et al. Chest 2019;155(6):1178-89

Mucus plug



Svenningsen et al. Chest 2019;155(6):1178-89

Mucus plug

VDP, ventilation defect percent

TABLE 4] Multivariable Linear Regression Models to Predict MRI VDP

Variable	Unstandardized		Standardized	*P* Value
	B	SE	β	
Prebronchodilator MRI VDP ($R = 0.79$; $R^2 = 0.62$, $P < .0001$)				
CT mucus score	0.82	0.17	0.79	**< .0001**
Sputum eosinophils %	NA	NA	NA	NA
Postbronchodilator MRI VDP ($R = 0.87$; $R^2 = 0.75$, $P < .0001$)				
CT mucus score	0.36	0.09	0.65	**.001**
Sputum eosinophils %	0.08	0.04	0.33	**.049**

Bold values denote statistical significance. β = standardized regression coefficient; B = unstandardized regression coefficient; NA = not added to model; VDP = ventilation defect percent.

Svenningsen et al. Chest 2019;155(6):1178-89

CONTENTS

Mosaic lung attenuation

- Mosaic lung attenuation (Inspiratory/expiratory scan)

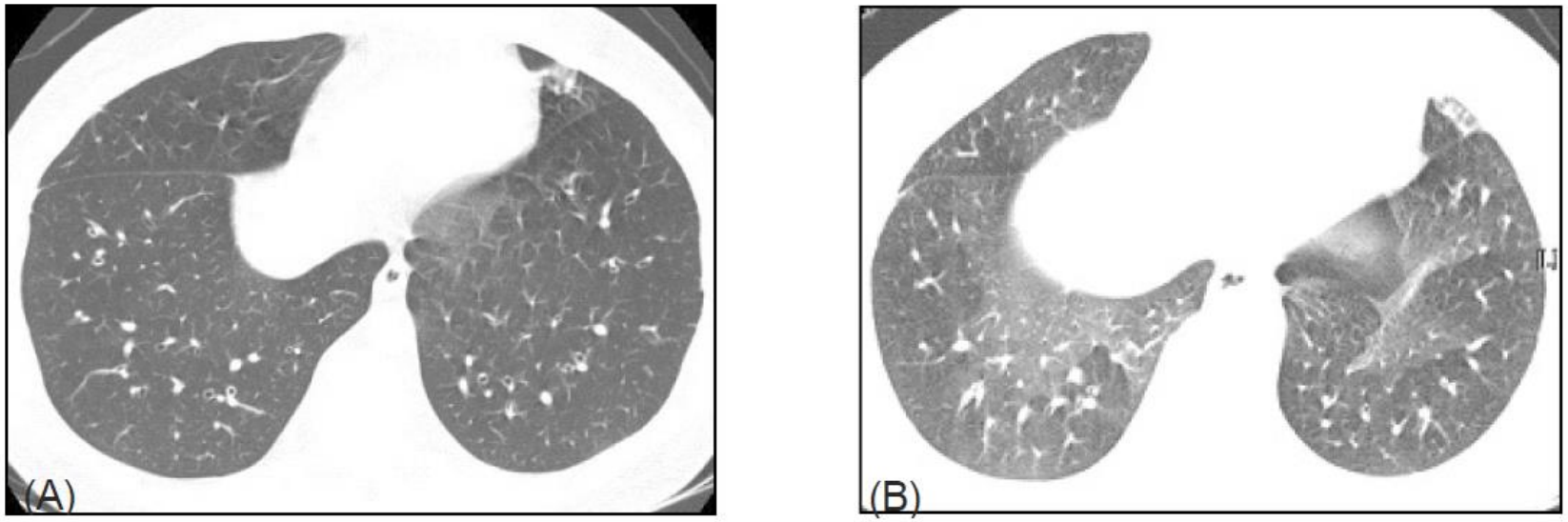


Figure 5. Air trapping in patient with bronchial asthma. (A) HRCT scan obtained at level of liver dome shows diffuse bronchial wall thickening without area of low attenuation during end-inspiration. (B) HRCT scan obtained at same level shows geographic air trapping in both basal lungs during full expiration.

Park et al.
Tuberc Respir Dis
2005;59(6):591-9

Abnormal attenuation

- 다양한 천식 환자 102명 포함
- 폐기능과 CT 소견의 상관성

➔ LAA, WA 높을 수록 폐기능 저하

LAA% = **low attenuation area**/total lung area X 100

Table 3—*Correlation Coefficients (r values) of Univariate and Stepwise Multiple Regression Analyses for Pulmonary Function Tests**

Variables	Univariate Regression Analysis		Multiple Regression Analysis
	LAA%	WA%	LAA% and WA%
FVC, % predicted	−0.159†	−0.437‡	0.482‡
FEV_1, % predicted	−0.529‡	−0.338‡	0.659‡
FEV_1/FVC, %	−0.650‡	−0.192†	0.700‡
PEFR, % predicted	−0.395‡	−0.487‡	0.660‡
RV/TLC, %	0.378‡	0.422‡	0.597‡
DLCO/VA, mL/min/mm Hg/L	−0.683‡	0.030†	NA

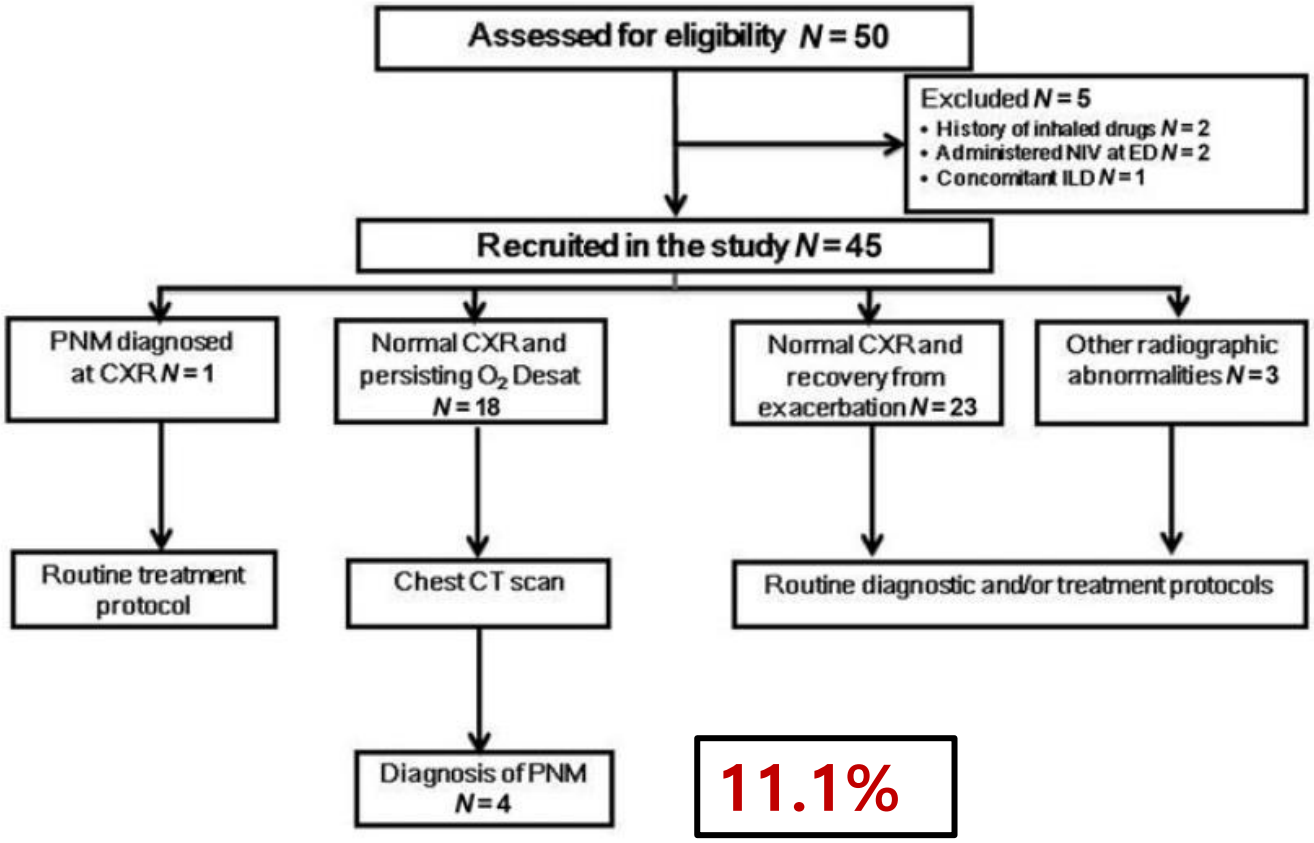
*PEFR = peak expiratory flow rate; RV/TLC = residual volume/total lung capacity; DLCO/VA = diffusing capacity of the lung for carbon monoxide/alveolar volume; NA = stepwise multiple regression analysis showed no additional predictive value of including WA%. Data reprinted with permission from Nakano et al.[17]
†Not significant. p Values were adjusted for multiple comparisons.
‡$p < 0.001$.

Nakano et al.
Chest
2002;122:271S-275S

CONTENTS

Pneumomediastinum

- Asthma attack administered at the ER in severe asthma patients



Vianello et al. J Asthma 2018;55(9):1028-34

Table 1. The patients' anthropometric, clinical, and blood gas data at baseline, their diagnosis and outcome. (ICS = Inhaled Corticosteroids; LABA = Long-Acting ß$_2$-Agonists; MAB = Monoclonal Antibodies; MV = Mechanical Ventilation; NA = Not Applicable; HFNC = High-Flow Nasal Cannula; PNM = Pneumomediastinum; SC = Systemic Corticosteroids). *P*-values refer to differences between patients with PNM and those with an uncomplicated course. (*With supplemental oxygen).

No of Subjects	All Cases 45	Patients with PNM 5	Pts with an Uncomplicated Course 40	*P*-value NA
Age, yrs (median, range)	46 (17–73)	21 (17–21)	49.5 (20–73)	<0.001
Gender (males, females)	13 (28.8%), 32 (71.2%)	2 (40%), 3 (60%)	11 (27.5%), 29 (72.5%)	0.6174
BMI, (mean ± SD), kg/m^2	25.43 (16.33–43.13)	21.40(18.13–31.98)	25.39 (16.33–34.21)	0.4350
Smoking history				
– Smoker	5 (11.2%)	2(40%)	3 (7.5%)	0.0874
– Non smoker	40 (88.8%)	3 (60%)	37 (92.5%)	
Predisposing factors				
– Atopy	25 (55.5%)	5 (100%)	20 (50%)	0.0562
– Alternaria sensitization	2 (4.4%)	2 (40%)	0 (0%)	0.0101
Regular asthma medication				
– ICS	41 (91.1%)	3 (60%)	38 (95%)	0.0551
– ICS + LABA	23 (51.1%)	2 (40%)	21 (52.5%)	0.6652
– SC	21 (46.6%)	0 (0%)	21 (52.5%)	0.0514
– MAB (Omalizumab)	2 (4.4%)	0 (0%)	2 (5%)	1.0000
Presenting symptoms				
– Dyspnea	45 (100%)	5 (100%)	40 (100%)	1.0000
– Coughing	40 (88.8%)	5 (100%)	35 (87.5%)	1.0000
– Chest pain	15 (33.3%)	1 (20%)	14 (35%)	0.6511
– Neck pain	1 (2.2%)	1 (20%)	0 (0%)	0.1111
– Sore throat	3 (6.6%)	0 (0%)	3 (7.5%)	1.0000
PaO_2 at admission*, mmHg	67.1 (44.2–147)	72 (55–94)	67.6 (44.2–147)	0.6188
$PaCO_2$ at admission, mmHg	36.20 (18–57)	41 (25.6–44.8)	35 (18–57)	0.6695
No of pts receiving MV	0 (0%)	0 (0%)	0 (0%)	1.0000
No of pts receiving HFNC O_2 therapy	1 (2.2%)	1 (20%)	0 (0%)	0.1111
Hospital stay, days (median, range)	7 (3–15)	8 (4–12)	7 (3–15)	0.6939
No of pts discharged alive	45 (100%)	5 (100%)	40 (100%)	1.0000

Vianello et al.
J Asthma
2018;55(9):1028-34

Pneumomediastinum

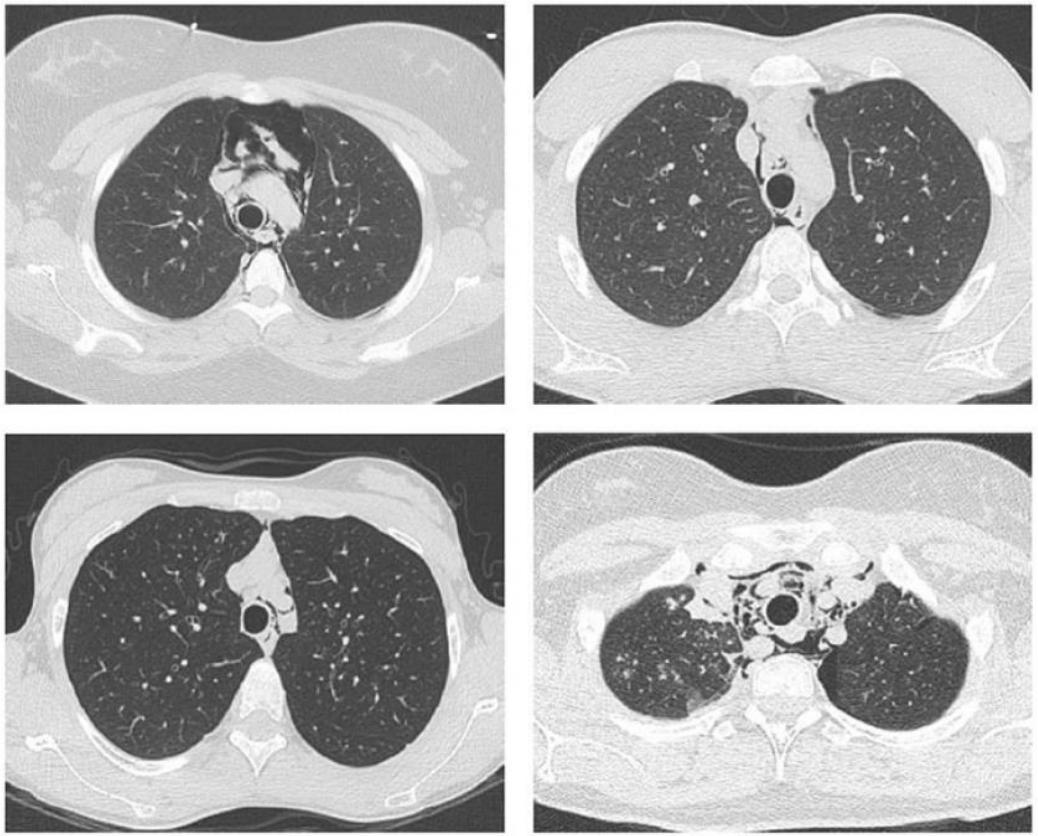


Figure 2. Computed tomography images of the chest demonstrating a pneumomediastinum in 4 of the patients with acute severe asthma exacerbation participating in the study.

Vianello et al.
J Asthma
2018;55(9):1028-34

Eosinophilic granulomatosis with polyangiitis (Churg-Strauss syndrome)

EGPA
Necrotizing granuloma with eosinophil infiltrate
1) History of asthma
2) Eosinophil >10%
3) Mono- or poly-neuropathy
4) Migratory non-fixed pulmonary infiltrates
5) Paranasal sinusitis
6) Extravasation of eosinophil on histology
(4 of 6)

Lee et al.
J Rheum Dis
2019;26(3):156-64

Eosinophilic granulomatosis with polyangiitis (Churg-Strauss syndrome)

TABLE 4 Computed tomography (CT) features in patients with eosinophilic granulomatosis with polyangiitis at diagnosis (n=136)

Chest CT feature	Number present	Feature present but not important	Moderately important feature	Prominent feature
Nodules (up to 30 mm)	15 (11%)	12 (9%)	2 (1%)	1 (1%)
Micronodules (<3 mm)	32 (24%)	19 (14%)	9 (5%)	4 (2%)
Centrilobular small nodules (<10 mm)	19 (14%)	11 (8%)	5 (4%)	3 (2%)
Ground-glass opacity	53 (39%)	20 (15%)	27 (20%)	6 (4%)
Consolidation	38 (28%)	9 (7%)	17 (12%)	12 (9%)
Mass (>30 mm)	7 (5%)	2 (1%)	2 (1%)	3 (2%)
Halo sign	5 (2%)	4 (2%)	1 (1%)	0
Reversed halo sign	1 (1%)	1 (1%)	0	0
Branching opacities (V- or Y-shaped)	16 (12%)	9 (7%)	7 (5%)	0
Tree in bud	13 (10%)	9 (7%)	4 (3%)	0
Mosaic attenuation (inspiration)	5 (4%)	3 (2%)	1 (1%)	1 (1%)
Air trapping (expiration)	5 (4%)	5 (4%)	0	0
Bronchial dilatation	21 (15%)	14 (8%)	7 (5%)	0
Bronchial wall thickening	43 (32%)	28 (21%)	13 (8%)	2 (1%)
Traction bronchiectasis	4 (3%)	4 (3%)	0	0
Mucous plugging	12 (9%)	8 (6%)	4 (3%)	0
Interlobular septal thickening	15 (11%)	10 (7%)	4 (3%)	1 (1%)
Pleural effusion	17 (12%)	6 (4%)	9 (7%)	2 (1%)
Pericardial effusion	11 (8%)	6 (4%)	4 (3%)	1 (1%)
Nodal enlargement >10 mm (mediastinal, hilar)	23 (17%)	16 (12%)	7 (5%)	0

Cottin et al.
Eur Respir J
2016;48:1429-41

Eosinophilic granulomatosis with polyangiitis (Churg-Strauss syndrome)

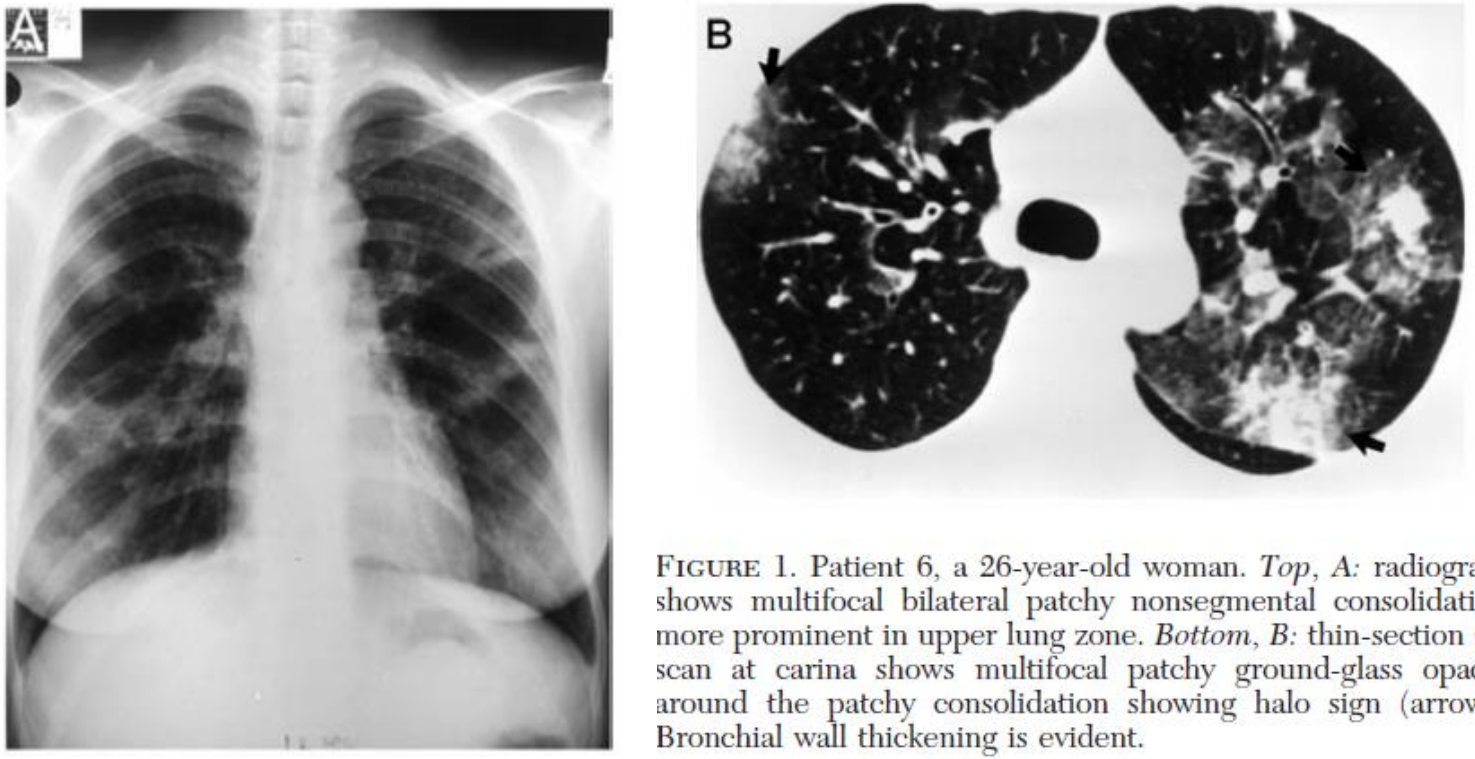
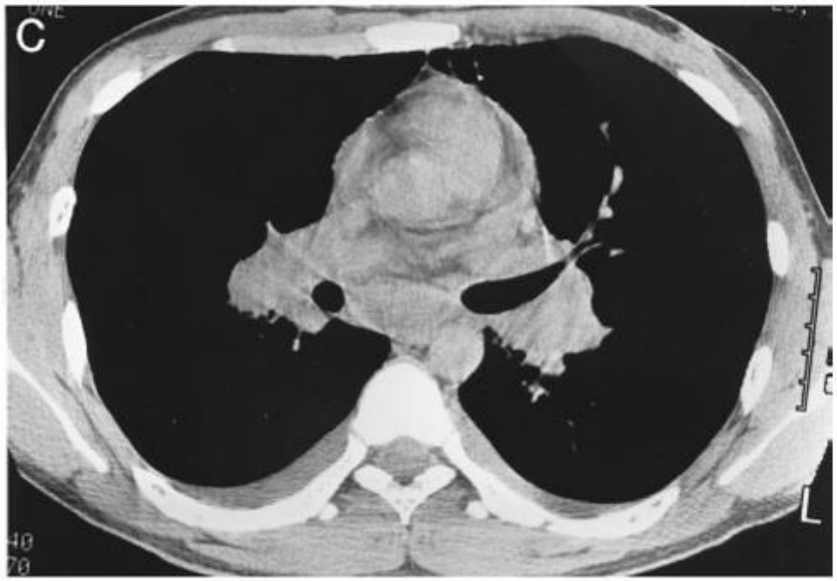


FIGURE 1. Patient 6, a 26-year-old woman. *Top, A:* radiograph shows multifocal bilateral patchy nonsegmental consolidation, more prominent in upper lung zone. *Bottom, B:* thin-section CT scan at carina shows multifocal patchy ground-glass opacity around the patchy consolidation showing halo sign (arrows). Bronchial wall thickening is evident.

Choi et al.
Chest
2000;117:117-24

Eosinophilic granulomatosis with polyangiitis (Churg-Strauss syndrome)



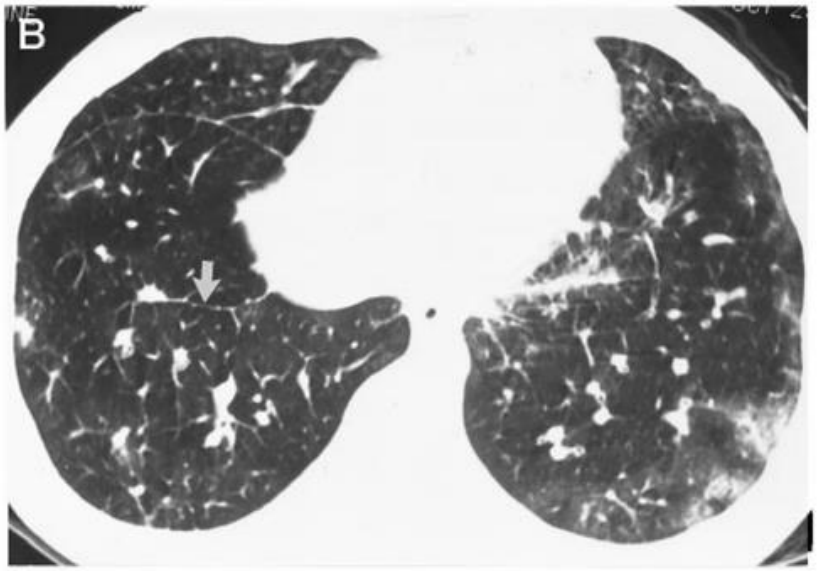


FIGURE 3. Patient 4, an 18-year-old man with pericardial involvement. *Top*, *A:* radiograph shows patchy consolidation at right lower lung, bilateral hilar lymph node enlargement, reticulonodular opacities, and increased cardiac size compared with his prior study (not shown). *Middle*, *B:* thin-section CT scan at lung bases shows multifocal ill-defined areas of ground-glass opacity associated with numerous nodular lesions in subpleural region. Note interlobular septal thickening (arrow), increased vascular diameters, and bronchial wall thickening. *Bottom*, *C:* mediastinal setting of CT scan at subcarinal level shows enlargement of subcarinal and both hilar lymph nodes and bilateral pleural effusions.

Choi et al.
Chest
2000;117:117-24

Allergic bronchopulmonary aspergillosis (ABPA)

- ABPA diagnostic criteria

Table 2. Diagnostic criteria for allergic bronchopulmonary aspergillosis (ABPA) according to Rosenberg-Patterson, adapted from Shah A et al. [44].

Diagnostic Criteria
Major
Asthma
Presence of transient pulmonary infiltrates (fleeting shadows
Immediate cutaneous reactivity to *A. fumigatus*
Elevated total serum IgE
Precipitating antibodies against *A. fumigatus*
Peripheral blood eosinophilia
Elevated serum IgE and IgG to *A. fumigatus*
Central/proximal bronchiectasis with normal tapering of distal bronchi
Minor
Expectoration of golden-brownish sputum plugs
Positive sputum culture for *Aspergillus* species
Late (Arthus-type) skin reactivity to *A. fumigatus*

Lattanzi et al. Pathogens 2020;9;716

Allergic bronchopulmonary aspergillosis (ABPA)

- Among 255 asthma patients

➔ 218 (86.8%): atopic

➔ 47 (21.6%): SPT positive to *Aspergillus fumigatus* (AF)

➔ 9-13 (**25.7-37.1%**) of 35 (SPT positive to AF): **ABPA**

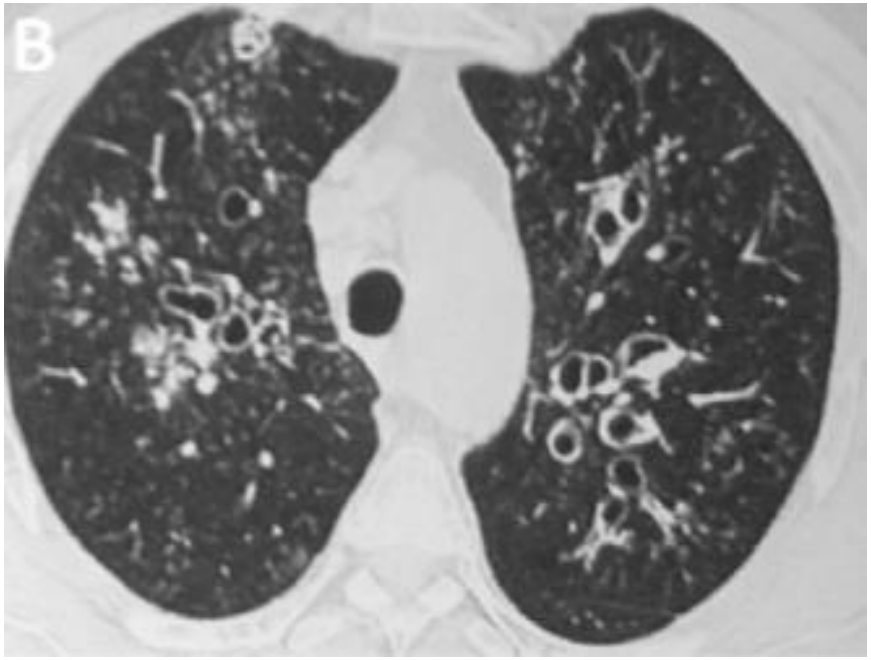
Table 2—*Diagnostic Criteria of Prospectively Recruited Asthma Patients Who Are SPT-Positive for AF Who Satisfied All Essential Criteria for ABPA**

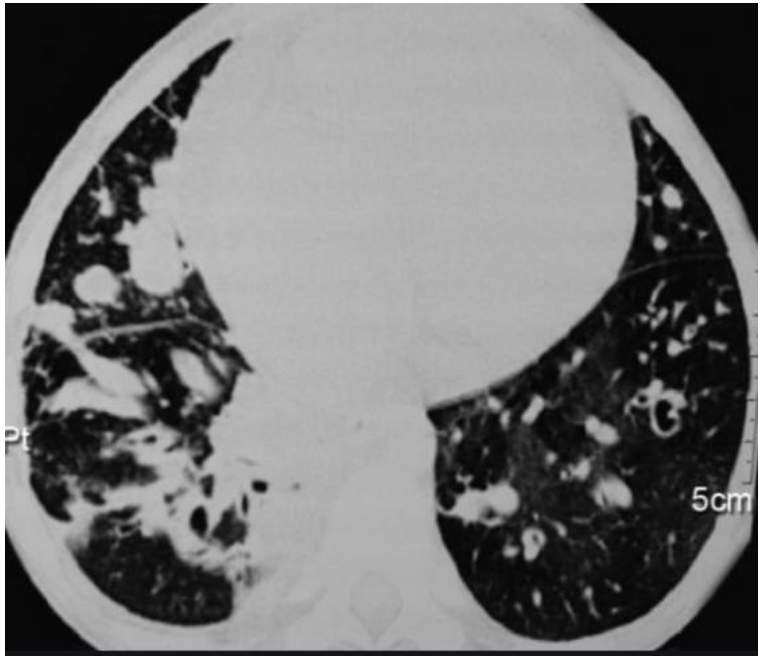
Age, yr	Sex	SPT AF, mm	AF-Specific IgE	IgE, ng/mL	Pulmonary Infiltrates	Central Bxs	Pptns	Eosinophils, cells/mm^3
53	M	8	3	12,991	−	+	0	0
44	M	6	3	1,471	−	+	1	550
65	M	5	4	38,616	+	−	0	540
33	F	5	4	1,236	−	+	0	550
65	F	4	4	17,352	−	+	2	90
48	M	9.5	3	4,697	−	+	0	370
45	F	9.5	4	1,414	+	+	1	950
50	F	9.5	4	10,450	−	+	6	640
42	M	16	4	2,186	−	+	0	120
53†	F	3	0	154	−	+	0	280
50†	F	5	0	110	−	+	2	200
59†	F	7	1	276	−	+	1	610
72†	F	3.5	2	530	−	+	0	140

*M = male; F = female; Bxs = bronchiectasis; Pptns = preciptins.
†Patient satisfies minimal essential criteria only.

Tam Eaton et al. Chest 2000;118:66-72

Allergic bronchopulmonary aspergillosis (ABPA)





Chronic eosinophilic pneumonia

- Chronic eosinophilic pneumonia (CEP)

➔ 중년의 여성에 흔함

➔ **50%가 천식 동반**

➔ 혈중 호산구/IgE 증가 동반 흔함

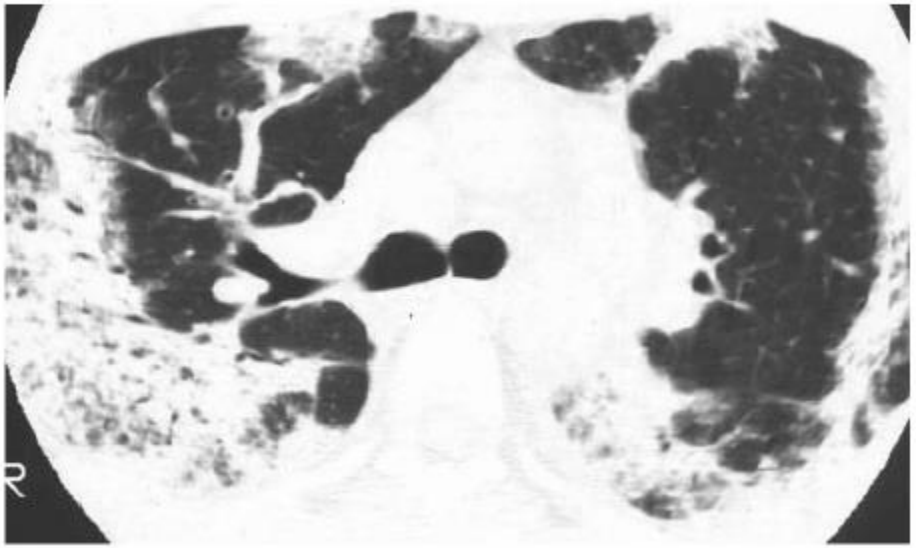
➔ BALF fluid 에서 호산구 증가

Jeong et al. Radiographics 2007;27:617-39

Chronic eosinophilic pneumonia

Figure 7. CEP in a 29-year-old man with 27.5% peripheral and 30% BAL fluid eosinophilia. **(a)** Chest radiograph shows airspace consolidation confined mainly to the peripheral lung (photographic negative shadow of pulmonary edema). **(b)** Transverse thin-section (1-mm collimation) CT scan (lung windowing) also shows airspace consolidation primarily involving the peripheral lung.

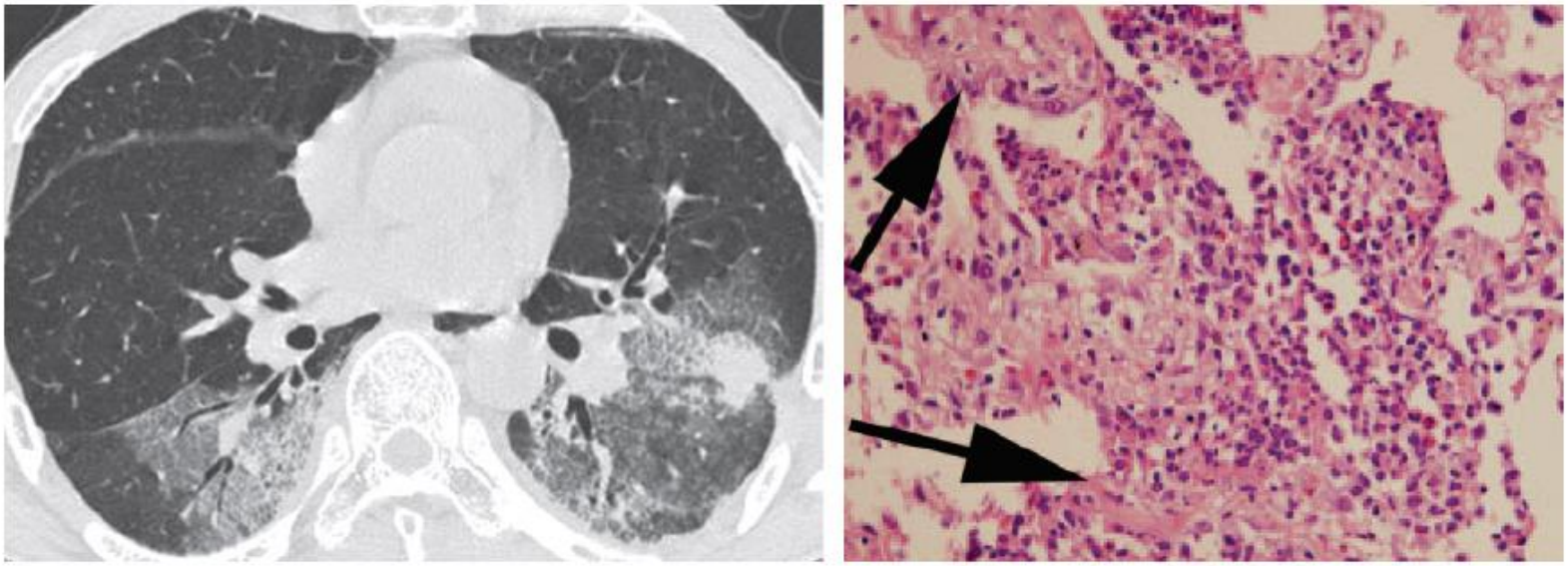
a.



b.

Jeong et al. Radiographics 2007;27:617-39

Chronic eosinophilic pneumonia



a. b.

Figure 6. CEP in a 59-year-old man with a 3-week history of severe cough and fever. The patient had 25% BAL fluid eosinophilia. **(a)** Thin-section (1-mm collimation) CT scan (lung windowing) shows ground-glass opacities with intralobular interstitial thickening in both lower lobes. **(b)** High-power photomicrograph (original magnification, ×400; H-E stain) of a transbronchial lung biopsy specimen shows infiltration of eosinophils and polymorphous inflammatory cells into the alveolar lumen and interstitium and a varying degree of interstitial fibrosis (arrows).

Jeong et al. Radiographics 2007;27:617-39

After thermoplasty

- After thermoplasty in 13 severe asthma patients (in 38 treated lobes)

TABLE 2 Early chest computed tomography findings obtained the day after bronchial thermoplasty

Parameter	Patients
Consolidations	38 (100)
All segments involved	25 (66)
>1 cm thickness away from bronchial lumen	11 (29)
Ground-glass opacities	38 (100)
All segments involved	23 (60)
Bubble-like lucencies or cavitation in consolidated lung[#]	26 (68)
Partial filling of bronchial lumen	36 (95)
Septal thickening	15 (39)
All segments involved	2 (5)
Pleural effusion or fissure thickening	26 (68)
Lobar volume loss	26 (68)
Complete lobar collapse[¶]	3 (8)
Non-treated lobe involvement[+]	12 (32)

Data are presented as n (%). BT: bronchial thermoplasty. [#]: microcavities that could correspond to minimal aerated bronchograms in predominantly filled bronchial lumen in 21 cases; [¶]: all cases of complete lobar collapse involved the left lower lobe; [+]: BT-untreated lobes involved the middle lobe (n=5), right lower lobe (n=4), left lower lobe (n=2) and left upper lobe (n=1).

Debray et al. Eur Respir J 2017;49:1601565

After thermoplasty

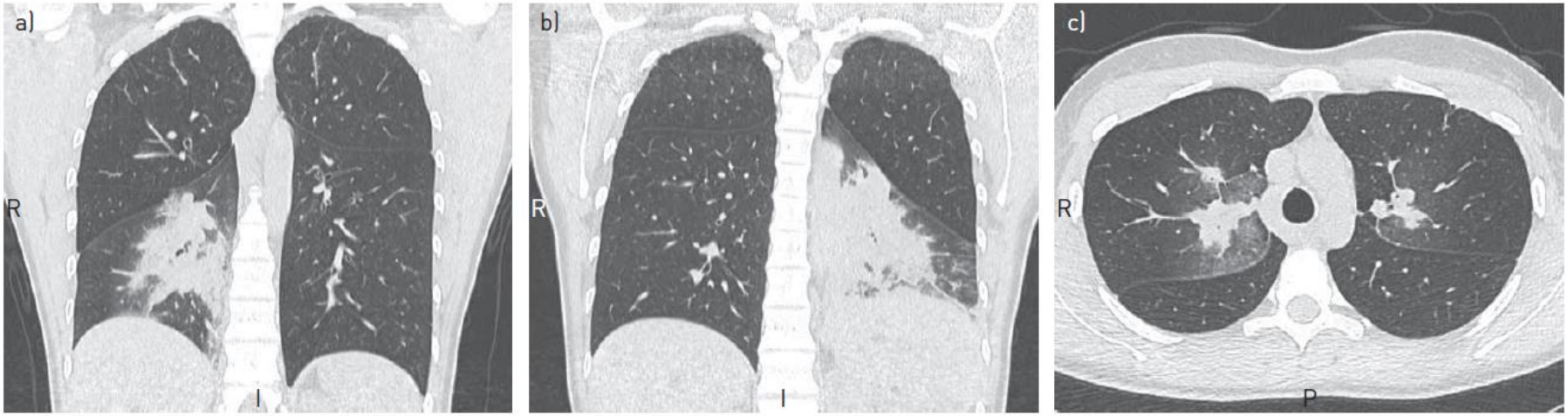


FIGURE 1 Chest computed tomography scans in the coronal plane the day after bronchial thermoplasty (BT) in a) the right lower lobe, showing peribronchial consolidations with bubble-like lucencies that completely disappeared 1 month later and b) the day after BT in the left lower lobe. Peribronchial consolidations are extensive and are associated with mild septal thickening and some lobar volume loss. c) Peribronchial opacities of limited extent are observed the day after BT in both upper lobes, which received the fewest number of activations. P: posterior; I: inferior; R: right.

Debray et al.
Eur Respir J
2017;49:1601565

After thermoplasty

한 달 후

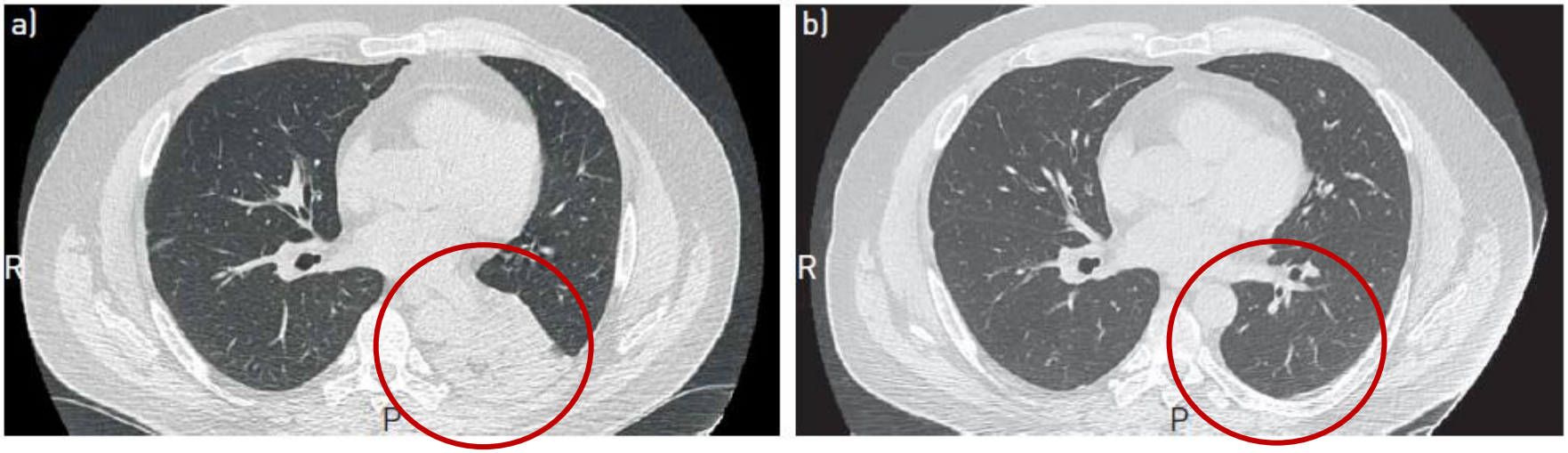


FIGURE 3 Chest computed tomography scans in the axial plane the day after bronchial thermoplasty in a) the left lower lobe, showing complete collapse of the treated lobe. b) The collapse has spontaneously resolved 1 month later.

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Eur Respir J
2017;49:1601565

After thermoplasty

일주일 후

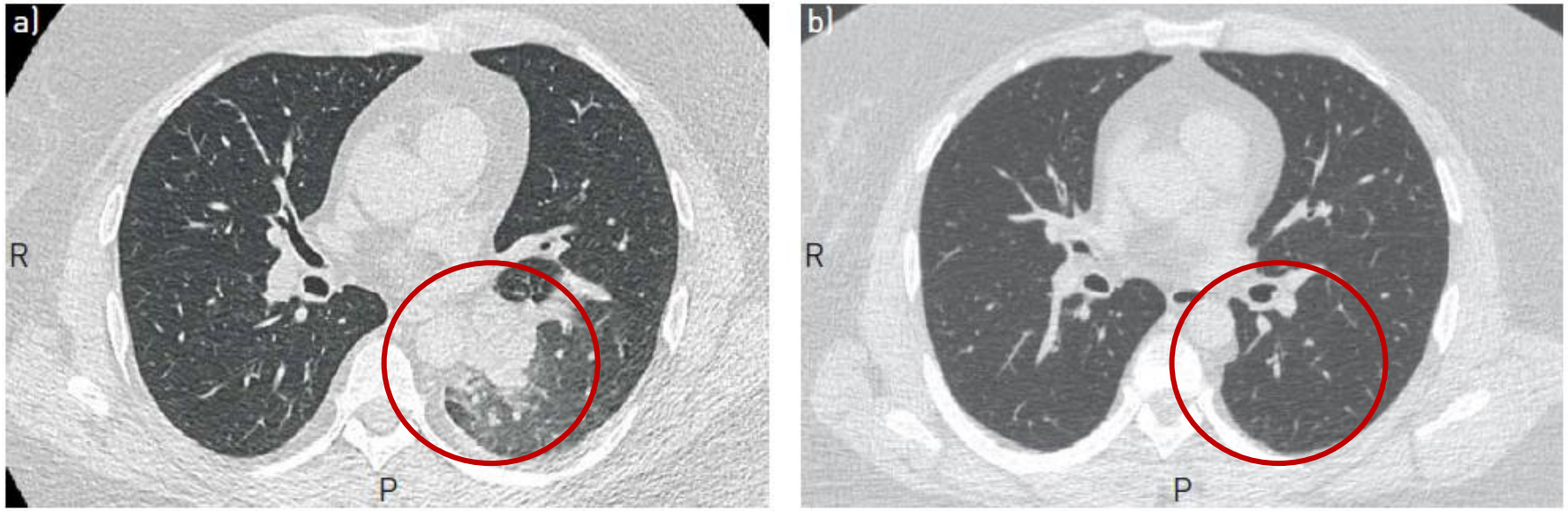

FIGURE 4 Chest computed tomography scans in the axial plane the day after bronchial thermoplasty in a) the left lower lobe and b) 1 week later showing the rapid disappearance of opacities.

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Eur Respir J
2017;49:1601565

Heart

- In COPD

➔ PA/A or eRV/eLV

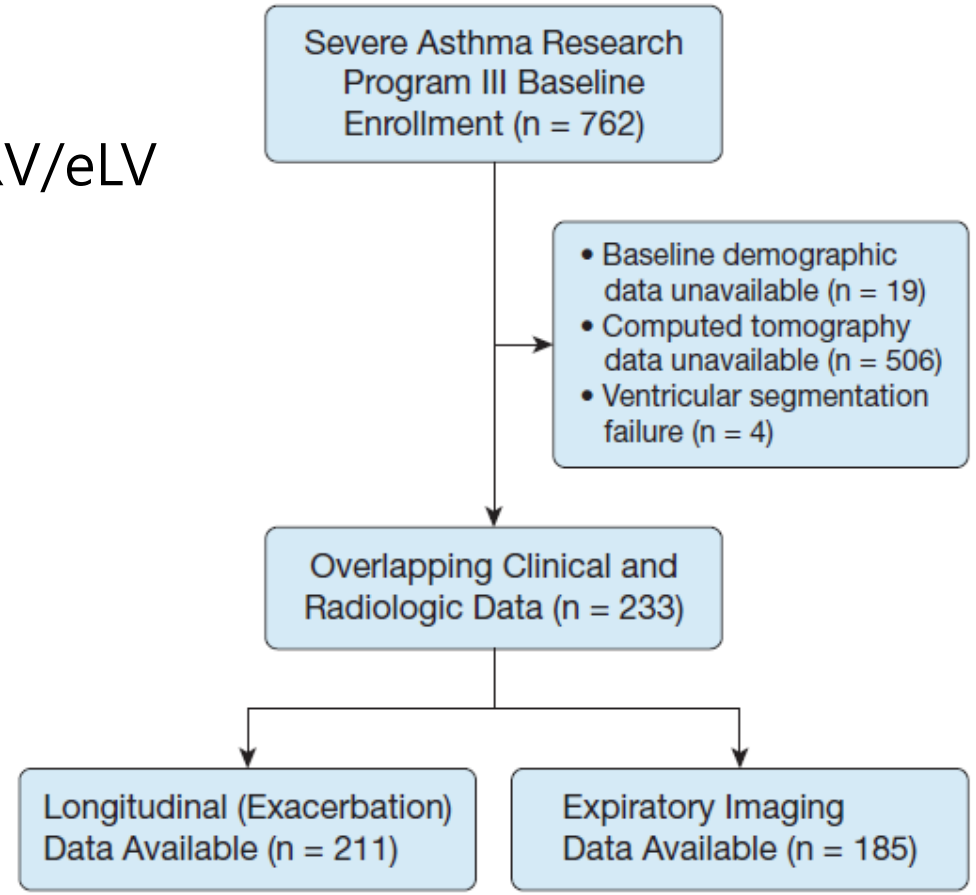
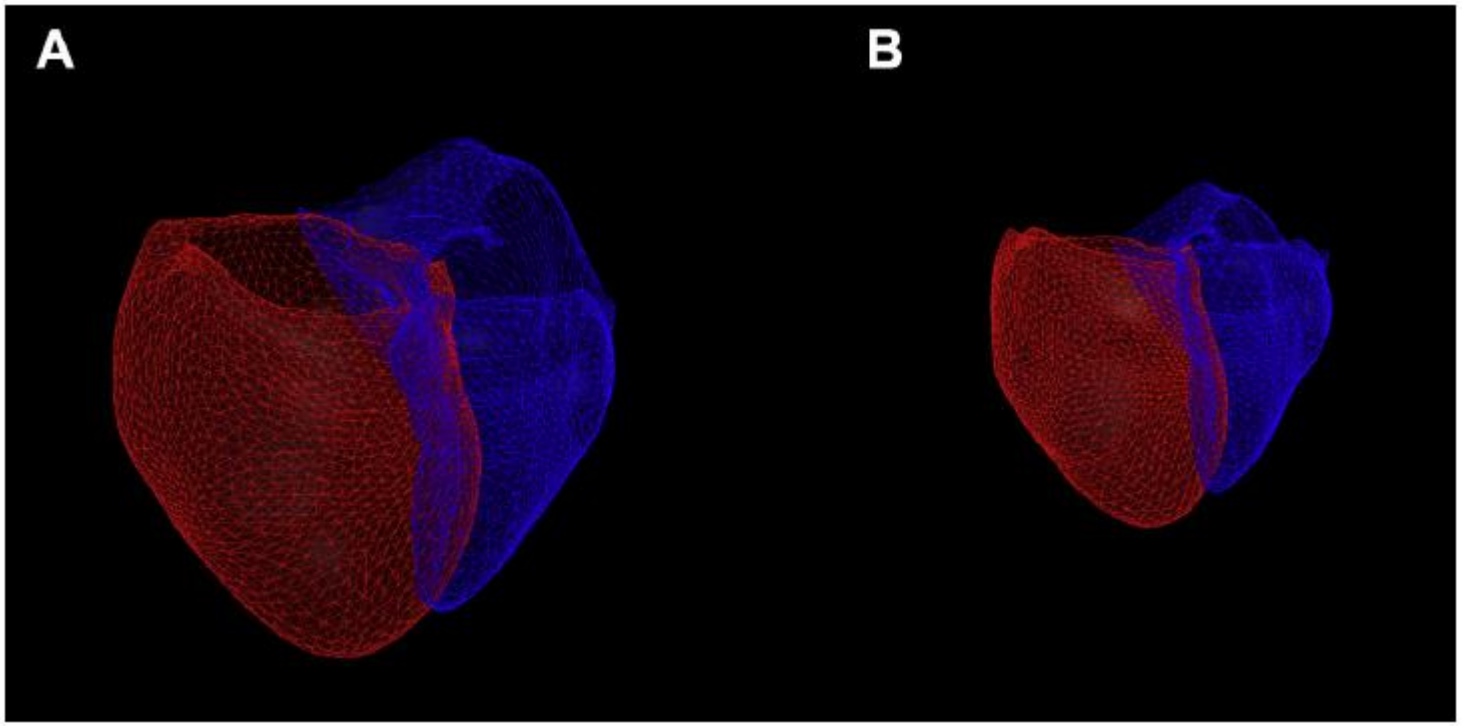


Figure 1 – *CONSORT diagram. CONSORT = Consolidated Standards of Reporting Trials.*

Ash et al. Chest 2020;157(2):258-67

Heart

- Mild/moderate asthma (Cardiac volume, 362,8 mL) (왼)
- Severe asthma (152.6 mL) (오른)
- RV(빨), LV(파)



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Heart

TABLE 4] Multivariable Associations Between Asthma Severity and Cardiac Ventricular Volumes

	eELVVI			eERVVI			eETVVI		
Asthma Severity	Difference	95% CI	*P* Value	Difference	95% CI	*P* Value	Difference	95% CI	*P* Value
Healthy Control Subjects as Reference									
Healthy control subjects	Reference			Reference			Reference		
Mild/moderate asthma	−12.1	−26.3 to 2.1	.095	−9.9	−19.7 to −0.1	.047	−22.0	−45.3 to 1.24	.063
Severe asthma	−20.3	−34.8 to −5.9	.006	−15.8	−25.8 to −5.8	.002	−36.1	−59.8 to −12.5	.003
Mild/Moderate Asthma as Reference									
Mild/moderate asthma	Reference			Reference			Reference		
Severe asthma	−8.3	−14.9 to −1.6	.015	−5.9	−10.4 to −1.3	.012	−14.1	−24.9 to −3.3	.011

Multivariable models adjusted for age, sex, race, BMI, systolic BP, percent predicted FEV_1, percentage of lung occupied by low-attenuation area, and height-normalized, CT scan-measured lung volume. See Table 1 legend for expansion of abbreviations.

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Heart

TABLE 7] Multivariable Associations Between Cardiac Volume Measures and Exacerbations in the Entire Cohort

Radiologic Measure	Incident Rate Ratio[a]	95% CI	*P* Value
Exacerbations in the Year Before Enrollment			
Estimated epicardial left ventricular volume index	1.41	0.97-2.05	.069
Estimated epicardial right ventricular volume index	1.72	1.21-2.44	.003
Estimated epicardial total ventricular volume index	1.60	1.10-2.33	.015
Exacerbations During Follow-Up			
Estimated epicardial left ventricular volume index	1.48	1.03-2.13	.035
Estimated epicardial right ventricular volume index	1.39	0.96-2.02	.079
Estimated epicardial total ventricular volume index	1.57	1.08-2.28	.020

Multivariable models adjusted for age, sex, race, BMI, systolic BP, low-attenuation area, height-normalized CT scan-measured lung volume, percent predicted FEV_1, Asthma Control Test score, and asthma severity (mild/moderate vs severe). Prospective analyses also adjusted for exacerbation reported in the year before enrollment.

[a]Incident rate ratios are expressed as those with lower volume compared with those with higher volume dichotomized at the median.

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Heart

TABLE 8] Multivariable Associations Between Cardiac Volume Measures and Exacerbations in the Subgroup With Severe Asthma

Radiologic Measure	Incident Rate Ratio[a]	95% CI	*P* Value
Exacerbations in the Year Before Enrollment			
Estimated epicardial left ventricular volume index	1.59	1.21-2.51	.012
Estimated epicardial right ventricular volume index	1.82	1.28-2.59	.001
Estimated epicardial total ventricular volume index	1.90	1.33-2.73	< .001
Exacerbations During Follow-Up			
Estimated epicardial left ventricular volume index	1.35	0.94-1.95	.104
Estimated epicardial right ventricular volume index	1.41	0.99-2.00	.054
Estimated epicardial total ventricular volume index	1.55	1.08-2.22	.017

Multivariable models adjusted for age, sex, race, BMI, systolic BP, low-attenuation area, height-normalized, CT scan-measured lung volume, percent predicted FEV_1, and Asthma Control Test score. Prospective analyses also adjusted for exacerbation reported in the year before enrollment.
[a]Incident rate ratios are expressed as those with lower volume compared with those with higher volume dichotomized at the median.

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SUMMARY

➢ **Airway wall thickness**
: 비교적 흔히 동반
: 천식 severity, 유병 기간, sputum neutrophil, 치료 유무와 연관

➢ **Bronchial dilatation and bronchiectasis**
: 중증 천식에서 흔히 동반, Fixed

➢ **Abnormal attenuation**
: 점차 악화되면 fixed low attenuation 관찰 가능

➢ **Others**
: pneumomediatinum
: Churg-strauss syndrome
: Allergic bronchopulmonary aspergillosis (ABPA)
: After thermoplasty
: Heart size


Thank you
With the Love of God, Free Humankind from Disease and Suffering
Severance