Impulse Oscillometry (IOS) in Asthma Diagnosis: Shifting from Pre-test to Post-test Probability

Asthma School 2026

2026 Oct 10 (SAT) 15:45-16:15

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강의 순서

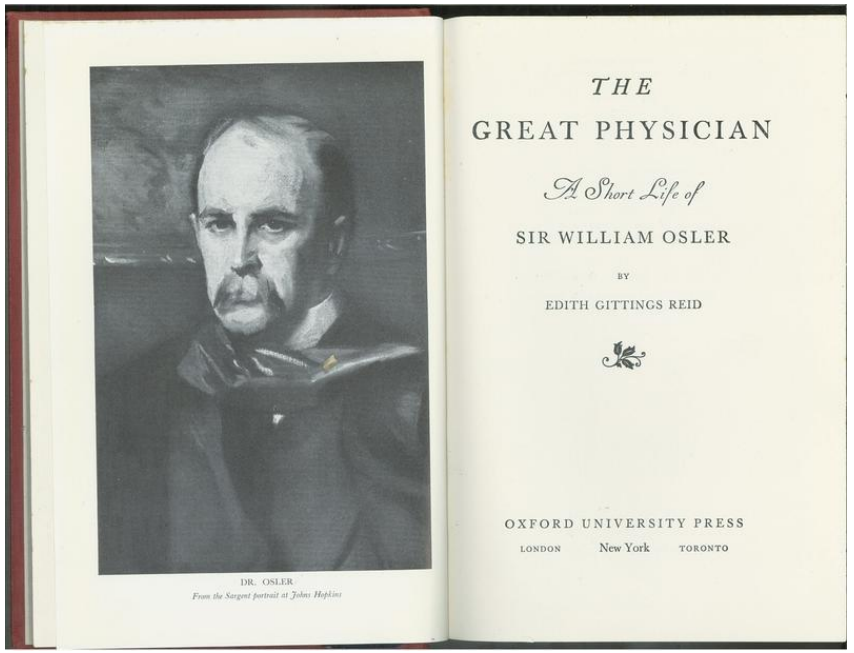
- 천식 진단: 사전검사확률에서 사후검사확률로
- 폐활량검사, 체적변동기록법, IOS 측정 parameters 차이
- 호흡진동법 (Respiratory Oscillometry) 용어와 이해
- IOS BDR의 천식 진단에서의 보완 역할
- 증례

Why is it important to understand how we make a diagnosis?

- In medicine, perfect certainty is rare.

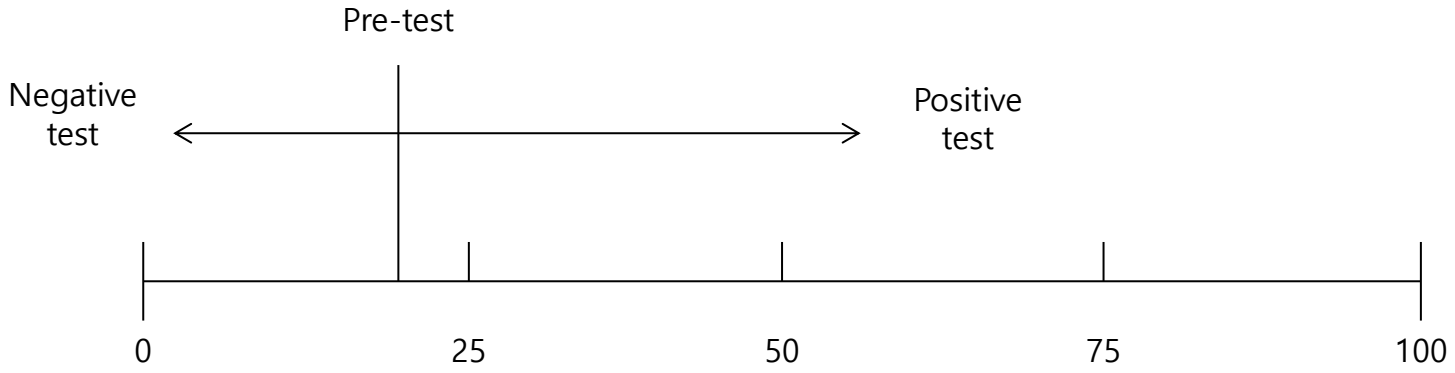
Medicine is a science of uncertainty and an art of probability.

- William Osler (1849-1919) -



Pre-test and Post-test probability

- Diagnostic process starts with pre-test probability
- Pre-test probability + Diagnostic test → Post-test probability



- Post-test probability (certainty of having or not having the disease): 질환 prevalence와 pre-test probability에 영향을 받는다.

Prevalence, positive predictive value, and Bayes theorem

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)}$$

$$P(\text{천식}|\text{검사+}) = \frac{P(+|\text{천식}) \cdot P(\text{천식})}{P(\text{검사+})} = \frac{(0.8)\times(0.05)}{(0.05)\times(0.8) + (0.95)\times(0.1)}$$

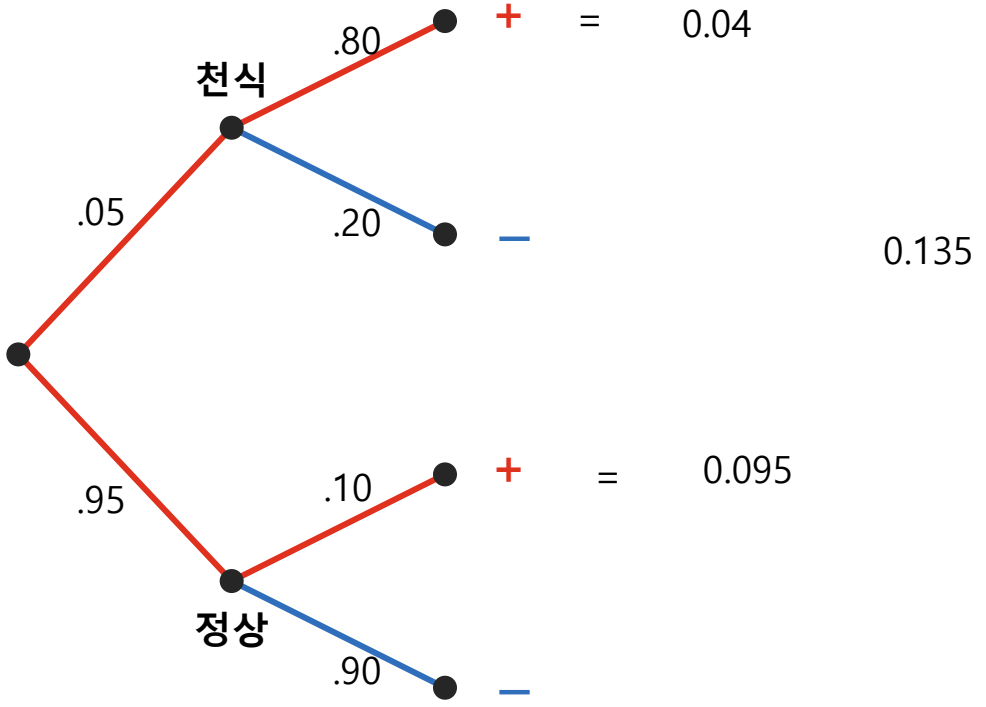
$$= 0.296 \approx 30\%$$

문제

- 20세 이상 성인, 국내 천식 유병률 5%
- 메타콜린 유발검사 (PC20=8 mg/mL 기준): 진양성률 (민감도) 80%, 위양성률 (1 – 특이도) 10%
- 30세 남성 흡연자로 흡연 시 객담만 있었는데 유발 검사 양성 판정을 받았다. 정말로 천식이 있을 확률은?

A = 천식 확진

B = 천식 유발검사(메타콜린) 양성



Example: Effect of Prevalence on Predictive Value

Prevalence 5% (저유병률 집단)

	천식 +	천식 -	
검사 +ve	45 (A)	95 (B)	140 (A+B)
검사 -ve	5 (C)	855 (D)	860 (C+D)
	50 (A+C)	950 (B+D)	1000

Prevalence = (A+C)/(A+B+C+D) = **5%**
Sensitivity = A/(A+C) = 90%
Specificity = D/(B+D) = 90%
PPV = A/(A+B) = **32%**
NPV = D/(C+D) = **99%**

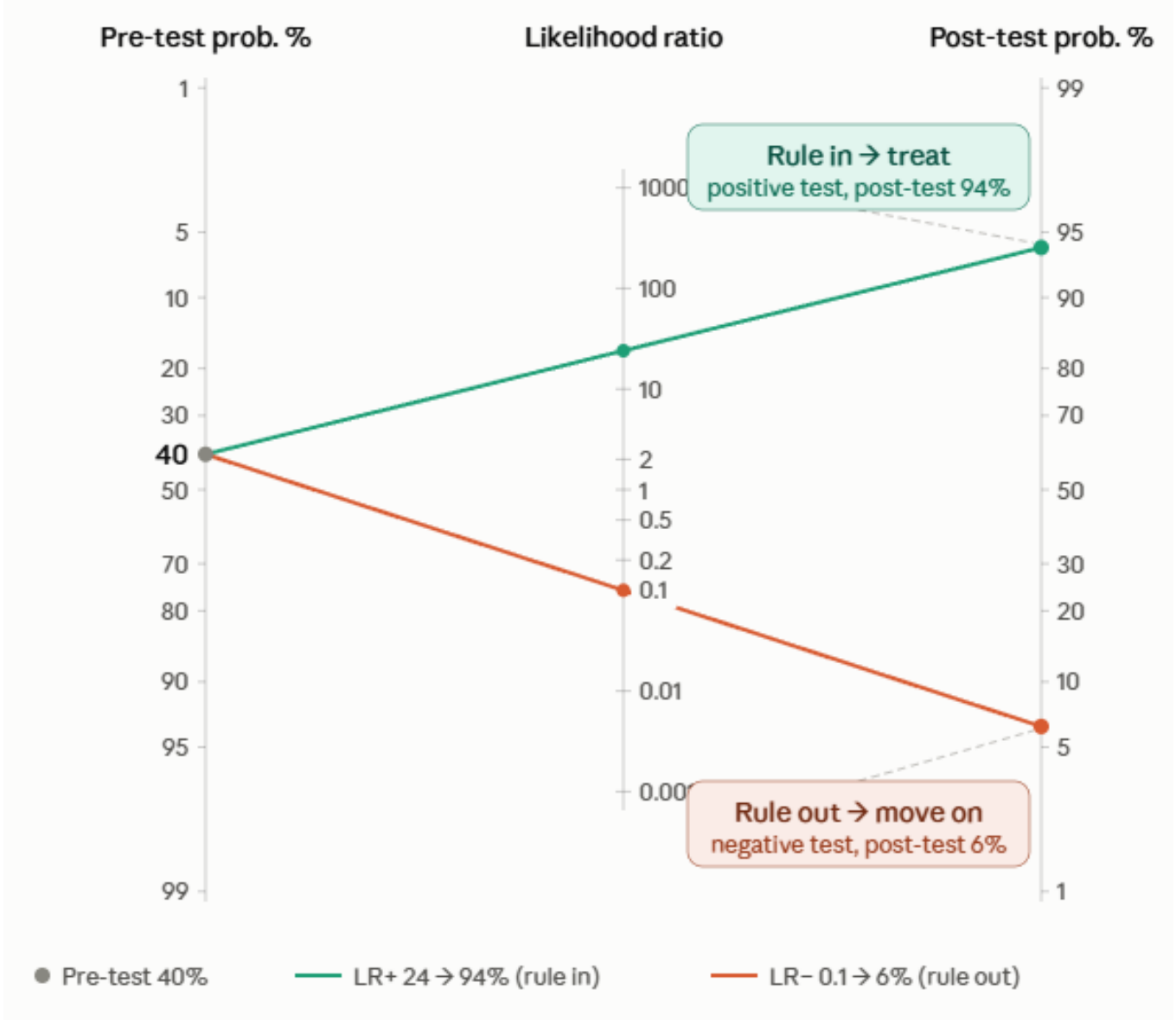
Prevalence 75% (고유병률 집단)

	천식 +	천식 -	
검사 +ve	675 (A)	25 (B)	700 (A+B)
검사 -ve	75 (C)	225 (D)	300 (C+D)
	750 (A+C)	250 (B+D)	1000

Prevalence = (A+C)/(A+B+C+D) = **75%**
Sensitivity = A/(A+C) = 90%
Specificity = D/(B+D) = 90%
PPV = A/(A+B) = **96%**
NPV = D/(C+D) = **75%**

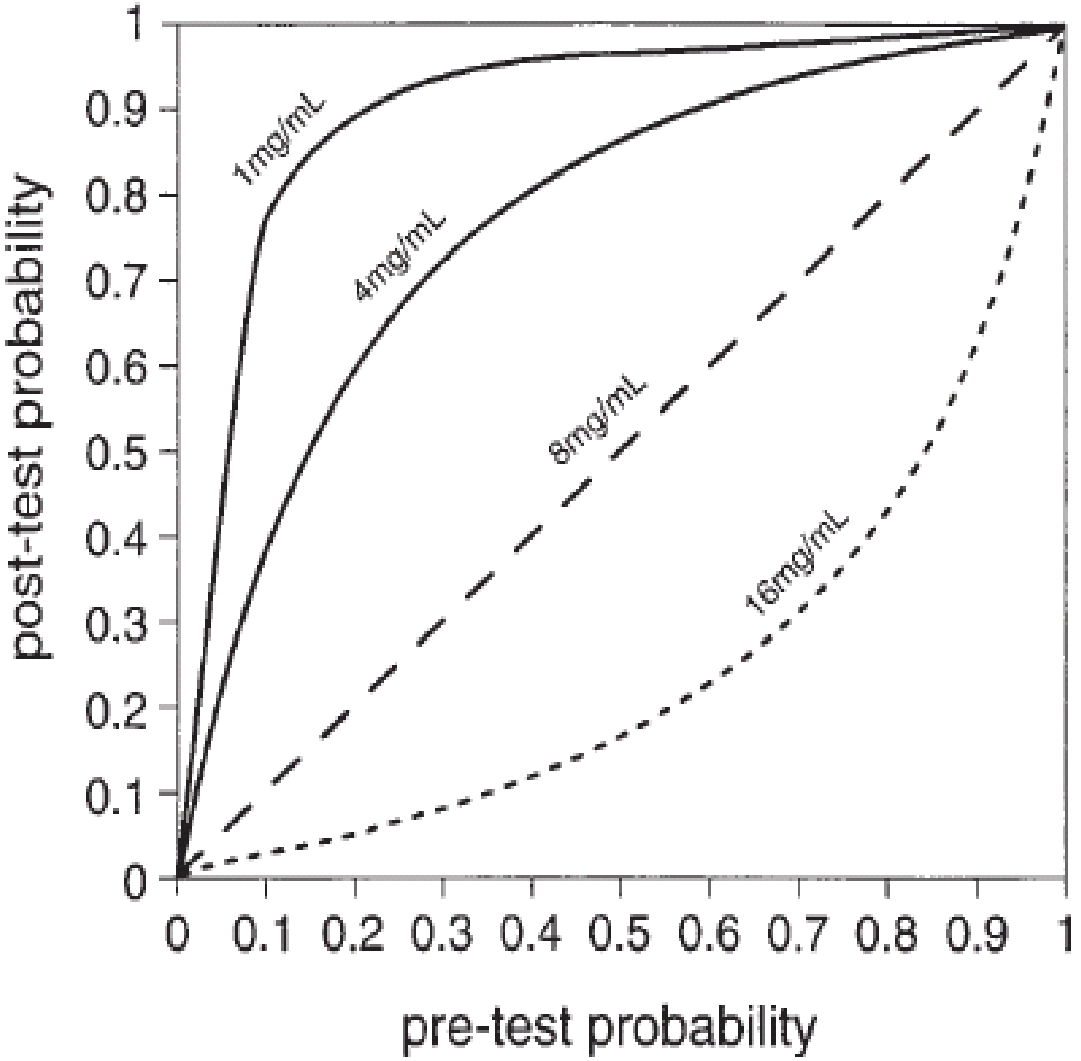
Likelihood ratio는 유병률과 무관하게 같다
LR+ = Sensitivity / (1 − Specificity) = 0.90 / 0.10 = **9.0** LR− = (1 − Sensitivity) / Specificity = 0.10 / 0.90 = **0.11**

Be certain enough to act – “Threshold for action”



- Probability of disease is high enough that you stop testing, rule it in, and start treating
- Probability of disease is low enough that you stop testing and rule it out

PC_{20} - 천식의 진단 확률 (직관적 이해)



폐활량검사 (Spirometry)

폐용적검사 (Lung Volume Measurement)

Impulse Oscillometry (IOS)

측정량으로 보는 차이: 유량 · 용적 · 압력 · 저항

저항 = Δ압력 ÷ 유량

Spirometry (폐활량검사)

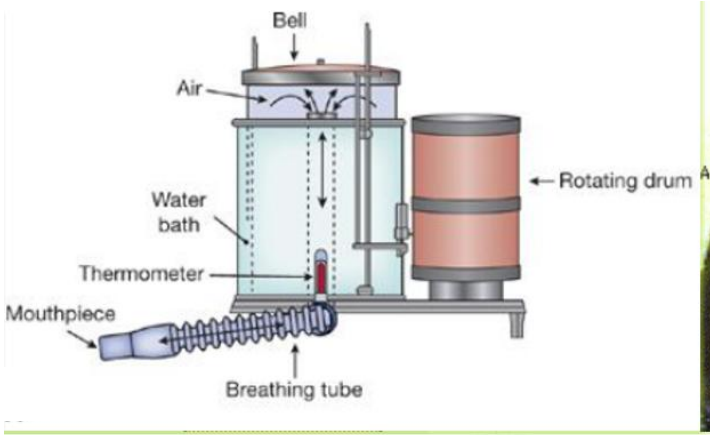
V과 V′만 측정 · P 없음 → 저항 계산 불가, 노력 의존성
최대 흡기 후 최대 노력 호기 검사로 소기도 평가 어려움.

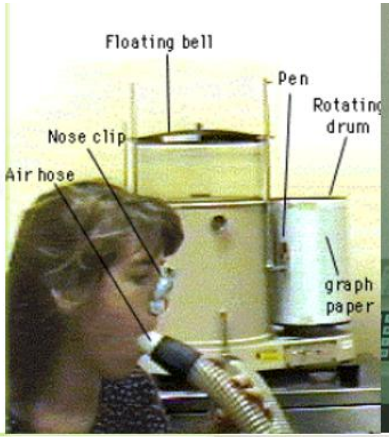
Lung Volume Measurement (체적변동기록법)

shutter 폐쇄 시 Pmouth ≈ Palv로 추정 · Raw = ΔPalv/V′

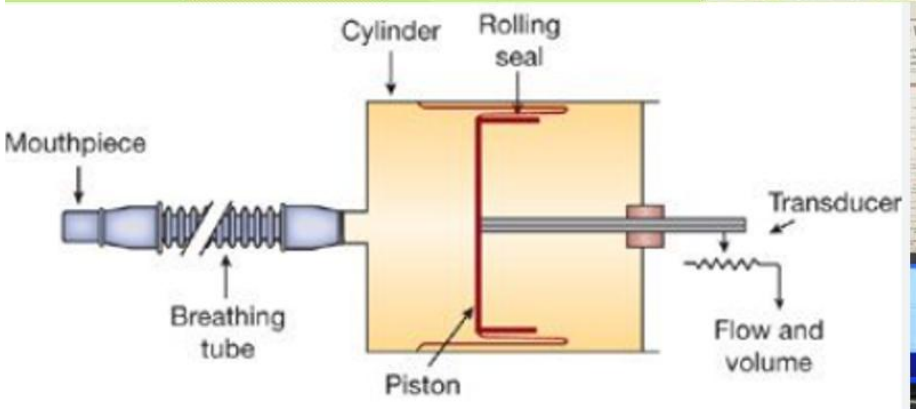
Impulse Oscillometry (IOS)

구강에서 P와 V′를 평상시 호흡에서 동시에 측정.











Oostveen E, et al. The forced oscillation technique in clinical practice. Eur Respir J. 2003;22(6):1026–1041.
Brashier B, Salvi S. Measuring lung function using sound waves: role of the FOT and IOS. Breathe. 2015;11(1):57–65.
Urbankowski T, Przybyłowski T. Methods of airway resistance assessment. Pneumonol Alergol Pol. 2016;84(2):134–141.

Spirometers: 용적형 (volume-type) vs. 유량형 (flow-type)

용적형 (volume-type)



Water seal spirometer·벨로우즈·
Dry rolling-seal spirometer
(예: Vmax 2130)

직접 재는 것: 용적
계산하는 것: 유량 (미분)

크고 무겁다 · 감염관리 어려움 · 빠른 변화에 둔함

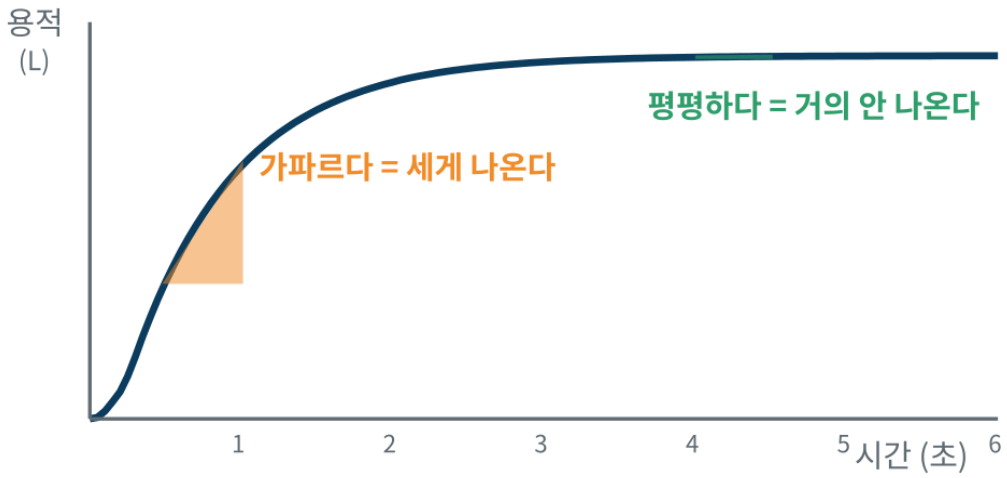
유량형 (flow-type)

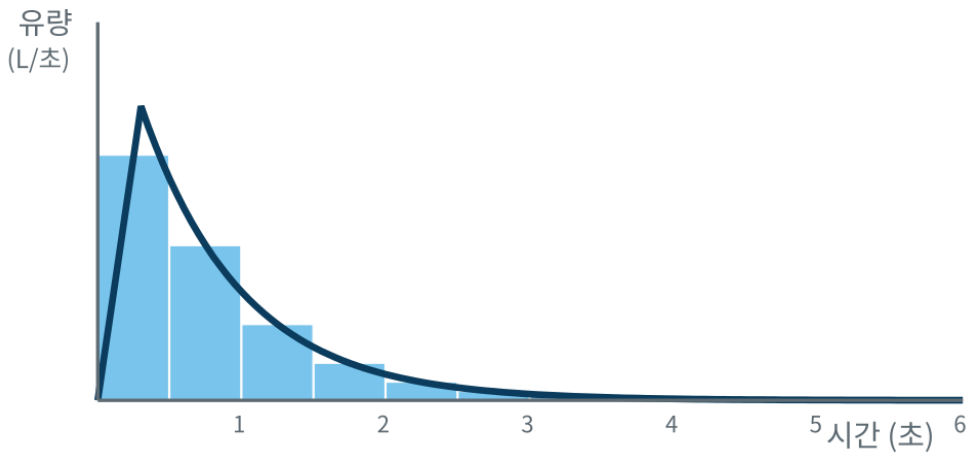


압력차(pneumotach)·열선·터빈·초음파
작고 가볍다 · 일회용 센서 · 흡기도 측정

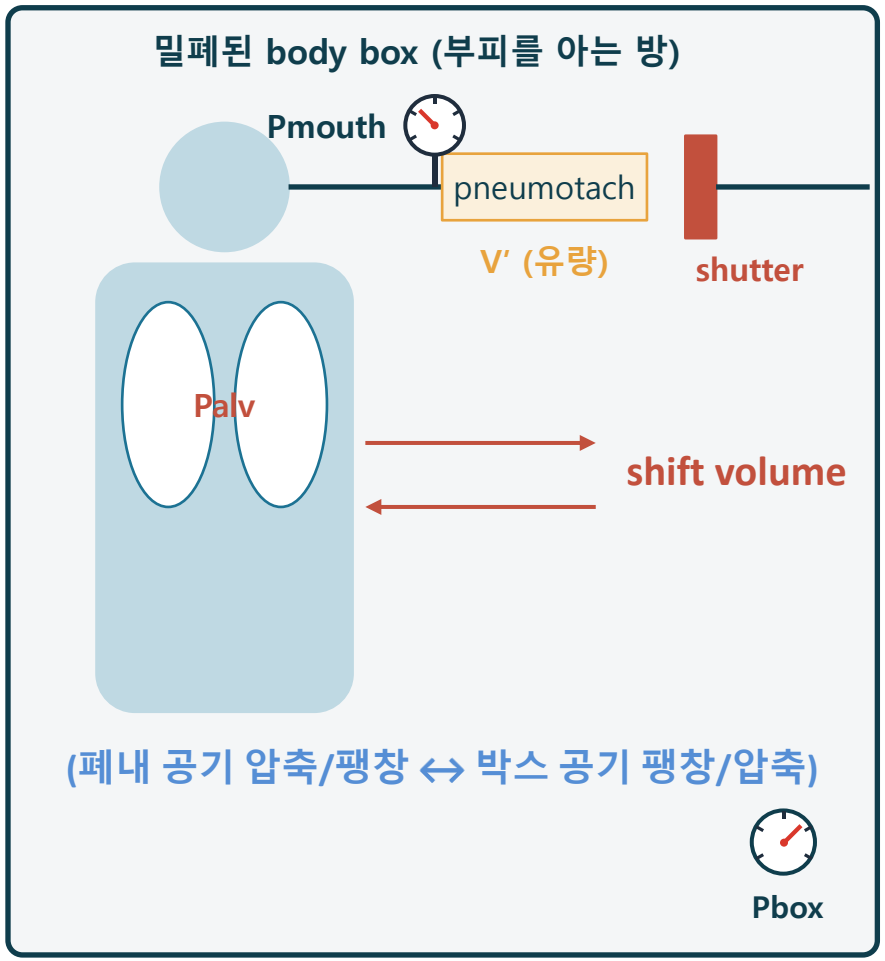
직접 재는 것: 유량
계산하는 것: 용적 (시간으로 적분)

요즘 장비 대부분 — FVC는 '더한 값'이다





체적변동기록법과 기도저항 측정



폐용적(②)과 기도저항(③)은 같은 panting에서 한 세트
→ F6006에 기도저항측정(F6009) 포함(별도 산정 불가)

1 **Body box에서 폐포압과** ΔPalv 측정 가능 **(Boyle 법칙)**

숨을 쉬려 힘을 주면 폐포 기체가 아주 조금 눌리거나 늘어난다(shift volume). 폐가 줄어든 만큼 밀폐된 박스의 공기는 늘어나므로 박스압이 변한다. 박스 부피를 알기 때문에 박스압 변화 = 폐포압 변화

2 **Shutter 닫고 panting → 폐용적 (TGV ≈ FRC)**

기류가 0이면 구강압 = 폐포압. ΔPmouth와 ΔPbox 기울기에 Boyle 법칙 (P·V = 일정)을 적용하면 그 순간 폐 안 기체량 TGV(≈ FRC)가 나온다.

3 **Shutter 열고 panting → 특이기도저항 (sRaw), 기도 저항 (Raw)**

pneumotach 유량 V′와 body box 내 압력을 동시에 그린 루프의 기울기로 기도 저항 계산 (Raw = ΔPalv/V′)

Criée CP et al. Body plethysmography — its principles and clinical use. Respir Med 2011;105:959–71.
(shift volume, sRaw = 유량–박스압 곡선 기울기의 역수, Raw = sRaw/TGV)

체적변동기록법 (s)Raw와 IOS의 Rrs:
같은 압력/유량 원리 기도저항 측정법, 다른 생리적 의미

	체적변동기록법 기도저항 Raw	IOS 임피던스 Zrs와 Rrs
측정 원리	박스압 변화로 Palv 추정 (shutter), Raw = ΔPalv/V′	구강에서 진동 가하고 압력과 유량을 동시 측정, Z(f) = P(f)/V′(f)
포함되는 요소	기도 (주로 대기도 우세)만	기도 (대기도 + 소기도) + 폐조직 + 흉벽 (호흡기계 전체)
호흡 양식	Panting (빠르고 얕은 호흡), 성문 개방 가정	안정 시 호흡 (tidal breathing), 20–30초
산출값	Raw, sRaw, sGaw (단일 값)	Rrs(f), Xrs(f), Fres, AX, R5–R20 (주파수 스펙트럼)
소기도 민감도	낮음 (대기도 저항이 지배)	높음 (저주파 R, X가 말초·불균질 반영)
전기 비유	직류 저항	교류 임피던스 (R; 소·대 기도 저항 + jX; 관성·탄성 포함)
장비·환경	밀폐 박스, 협조 필요	탁상형, 협조 최소, 침상·소아 가능

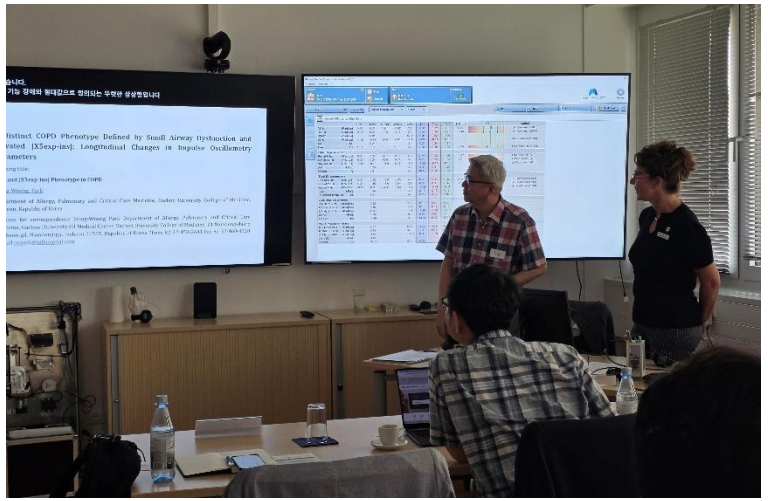
체적병동기록법 폐용적(F6006)과 같은 날 기도저항측정(F6009)은 별도 산정 불가:
IOS를 F6009로 청구하는 현행 관행에서는 폐용적검사를 같은 날 시행시 IOS 비용 산정 불가

Smith HJ, Reinhold P, Goldman MD. ERS Monograph 2005; Ch.5 (Raw는 기도만, Rrs는 흉벽·폐조직 포함); Criée CP et al. Respir Med 2011 (Body plethysmography review)

2026년 6월 22-23일, 독일 Höchberg, JAEGER 본사 방문 및 IOS 적용 워크숍











*With special thanks to **Margriet Kaldenbach** for generously sharing her lecture materials.*

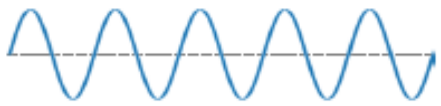
Terminology: FOT = IOS?

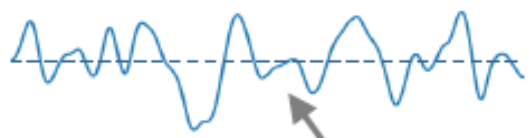
Clinical measurement → Respiratory Oscillometry (RO)

Historical terminology → Forced Oscillation Technique (FOT)

Excitation
RO/FOT methods

Single-frequency sine waves ≠ Pseudo Random Noise (PRN) ≠ Impulse Oscillometry (IOS)









TremoFlo device → Airwave Oscillometry System (AOS)



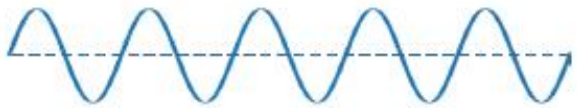
Vyntus™ IOS

DuBois AB, et al. Oscillation mechanics of lungs and chest in man. J Appl Physiol. 1956;8(6):587–594.
Michaelson ED, et al. Pulmonary mechanics by spectral analysis of forced random noise. J Clin Invest. 1975;56(5):1210–1230.
Oostveen E, et al. The forced oscillation technique in clinical practice. Eur Respir J. 2003;22(6):1026–1041.
Brashier B, Salvi S. Measuring lung function using sound waves: role of the FOT and IOS. Breathe. 2015;11(1):57–65.
King GG, et al. Technical standards for respiratory oscillometry. Eur Respir J. 2020;55(2):1900753.

Pressure, Flow, Resistance in FOT

1956 | 1975 | 1994

Single-frequency sinusoidal wave (sequential)

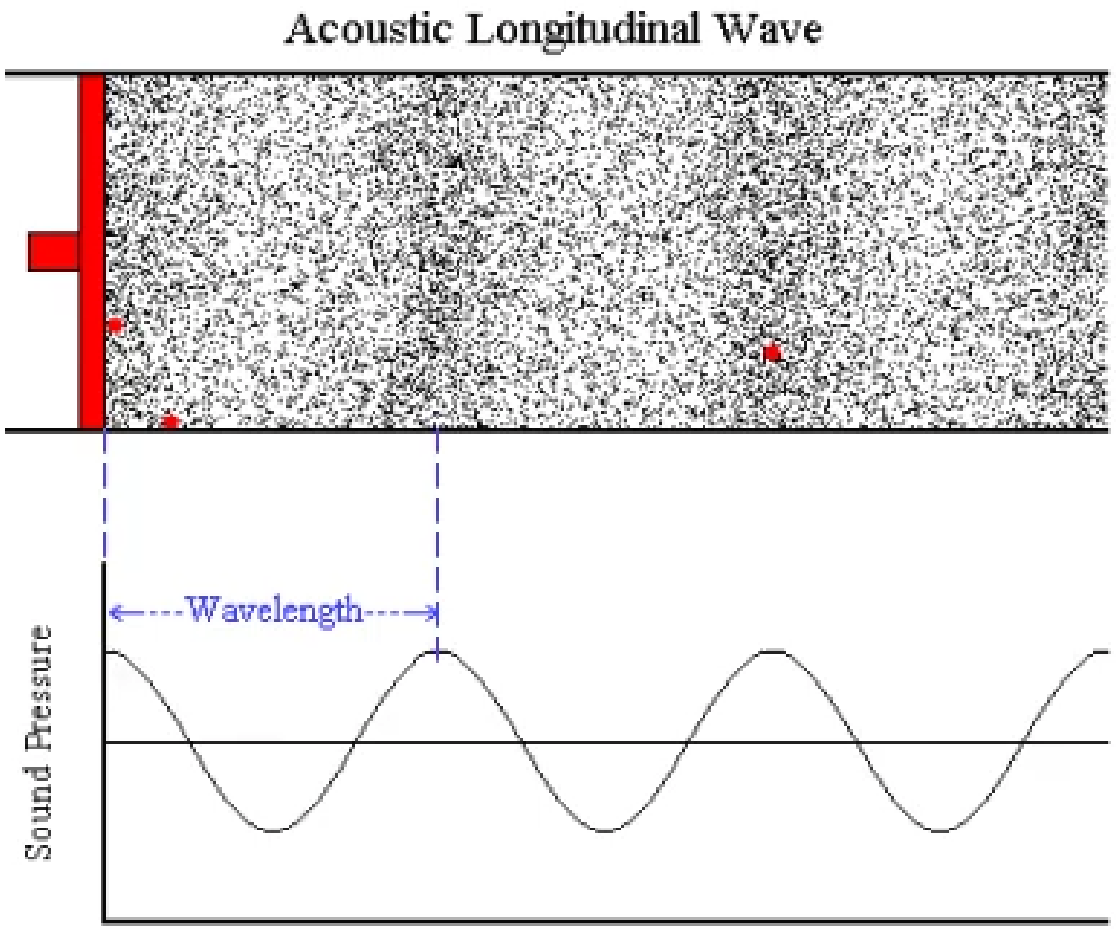


Pseudo Random Noise (PRN)

Impulse oscillometry (IOS)



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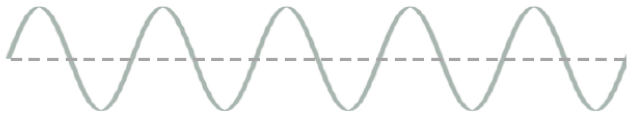
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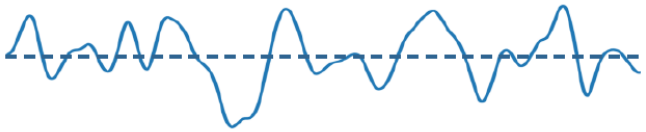
Fast Fourier analyzer & Pseudo Random Noise (PRN)

1956 | 1975 | 1994

Single-frequency sinusoidal wave (sequential)

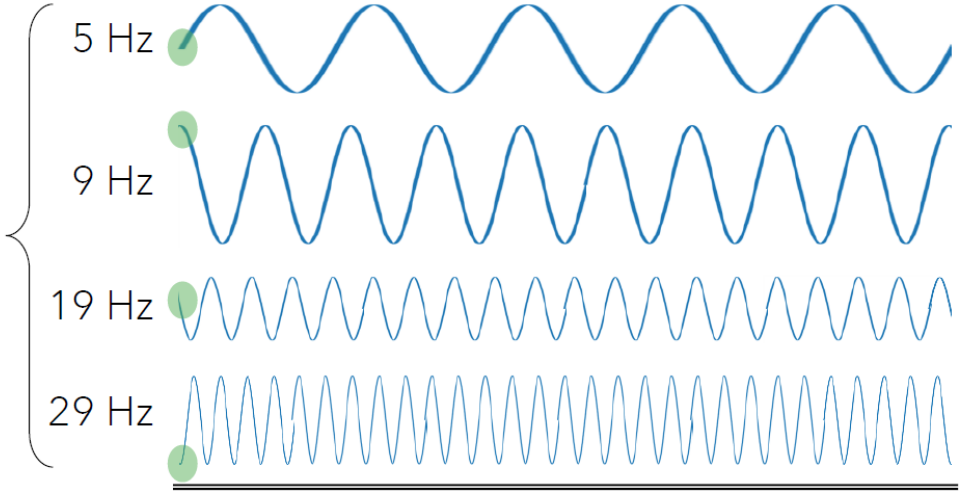


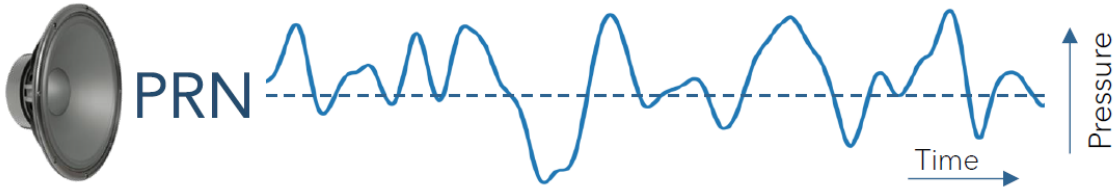
Pseudo Random Noise (PRN)



Impulse oscillometry (IOS)

Each sine wave has its own amplitude & phase





Fast and slow pressure changes over time

Forms of excitation: Pseudo Random Noise (PRN)

1956 | 1975 | 1994

Single-frequency sinusoidal wave (sequential)



Pseudo Random Noise (PRN)



Impulse oscillometry (IOS)



Tremoflo C-100 (Thorasys)



Resmon Pro (Restech)



PulmoScan (Cognitalabs)



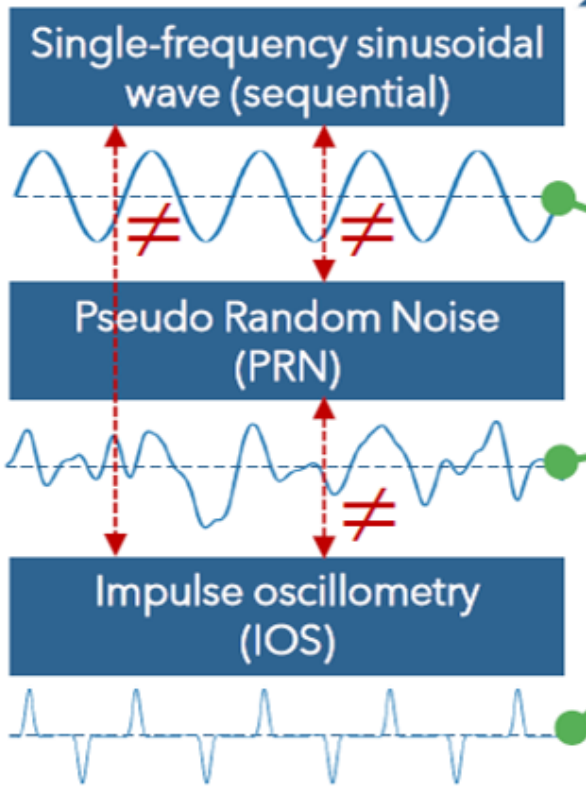
Q-i2 (Cosmed)



MostGraph-02 (Chest)

Forms of excitation: Impulse Oscillometry (IOS)

1956 → 1975 → 1994



Membrane behaviour	Frequency content
Continuous, smooth movement (same rhythm throughout)	One frequency at a time (e.g. 5, 10 , 20 Hz)
Continuous, irregular movement (multiple rhythms combined)	Multiple, discrete frequencies simultaneously (e.g. 5, 11, 19, 29 Hz)
Short movements with pauses in-between (~40ms, alternating direction)	Broadband, containing a range of frequencies (e.g. 5 to 35 Hz)



Vyntus™ IOS



DuBois AB, et al. Oscillation mechanics of lungs and chest in man. J Appl Physiol. 1956;8(6):587–594.
Michaelson ED, et al. Pulmonary mechanics by spectral analysis of forced random noise. J Clin Invest. 1975;56(5):1210–1230.
Vogel J, Smidt U. Impulse Oscillometry: Analysis of Lung Mechanics in General Practice and Clinic. Frankfurt: pmi Verlagsgruppe; 1994.

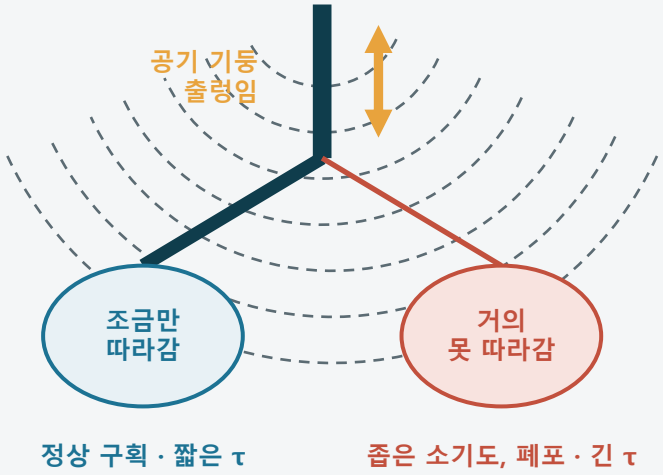
Fast vs. slow pressure changes (high vs. low frequencies)

~~"높은 주파수는 얕게, 낮은 주파수는 깊이 들어간다"~~

실제로는 모든 주파수가 말초까지 도달한다.

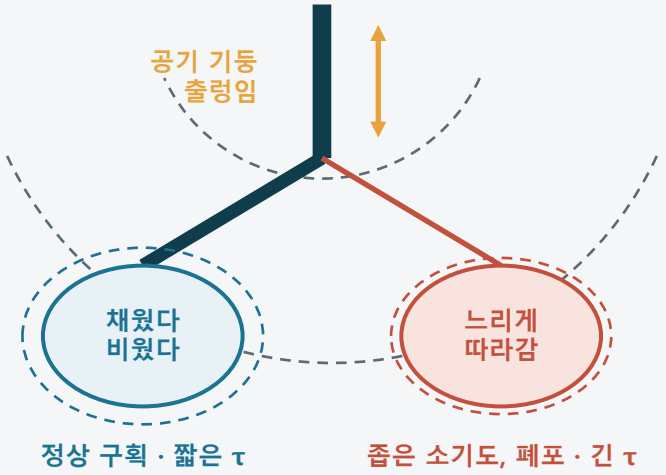
- 각 구획은 시간상수 τ = R·C만큼 늦게 반응한다
- 주기(1/f)가 τ보다 짧으면 그 구획은 부풀지 못하고, 진동은 **중심 기도에 갇힌다**
- 말초 협착이 많을수록 이 '갇힘'은 **더 낮은 주파수부터** 시작된다

20 Hz (주기 50 ms)

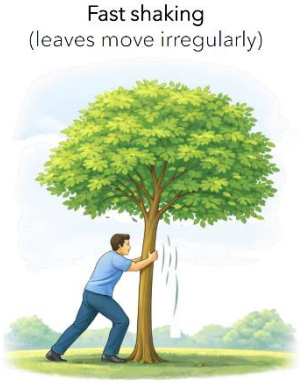


R20 중심 기도 저항 (관성 포함)

5 Hz (주기 200 ms)



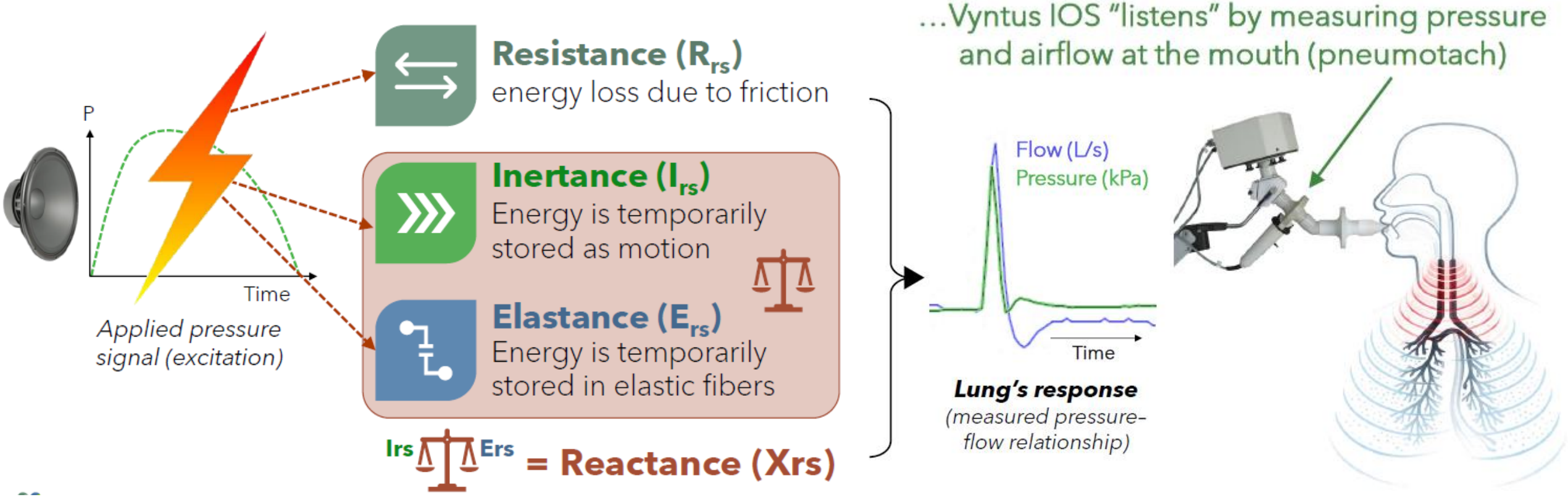
R5 전체 저항: 중심 + 말초 + 조직



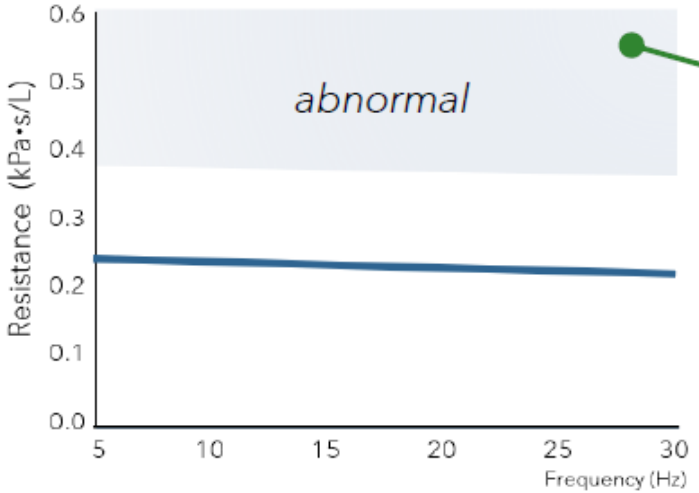


1. Kaminsky DA, et al. Clinical significance and applications of oscillometry. Eur Respir Rev. 2022;31(163):210208.
2. Bates JHT. Systems physiology of the airways in health and obstructive pulmonary disease. Wiley Interdiscip Rev Syst Biol Med. 2016;8(5):423–437.
3. Kaczka DW, Dellacà RL. Oscillation mechanics of the respiratory system: applications to lung disease. Crit Rev Biomed Eng. 2011;39(4):337–359.
4. Otis AB, et al. Mechanical factors in distribution of pulmonary ventilation. J Appl Physiol. 1956;8(4):427–443.
5. Brashier B, Salvi S. Measuring lung function using sound waves: role of the forced oscillation technique and impulse oscillometry system. Breathe. 2015;11(1):57–65.

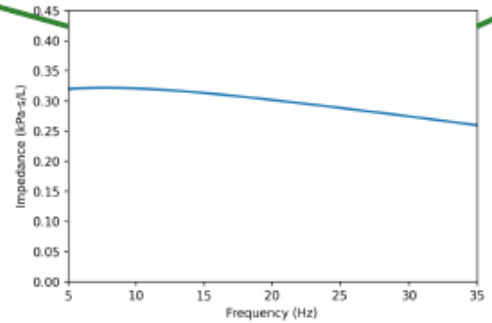
Impulse to measured lung response: What shapes the lung's response?



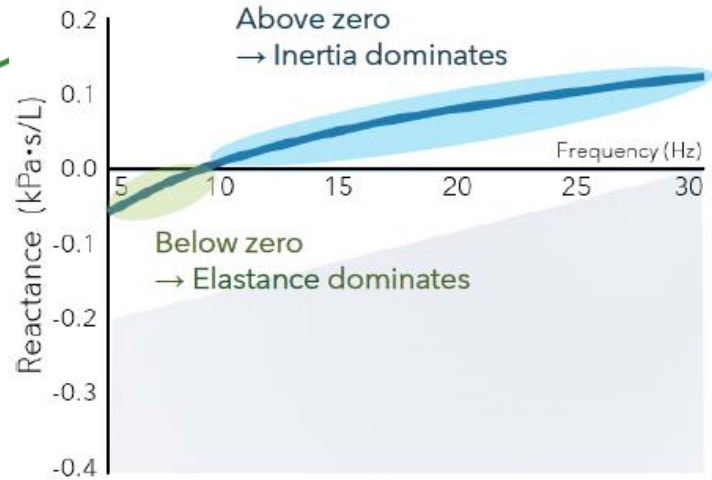
Resistance (Rrs)



Impedance (Zrs)



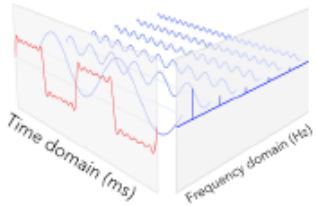
Reactance (Xrs)

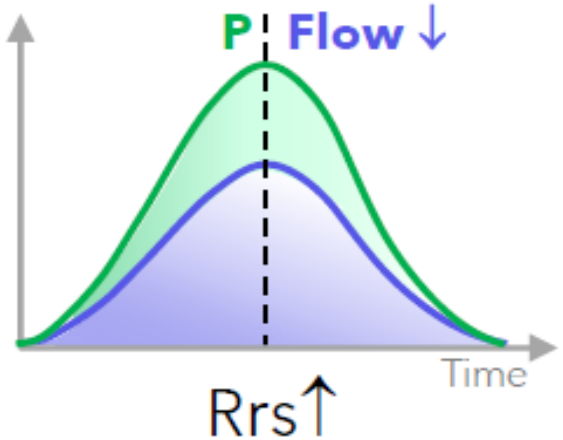


In-phase pressure and flow relationship

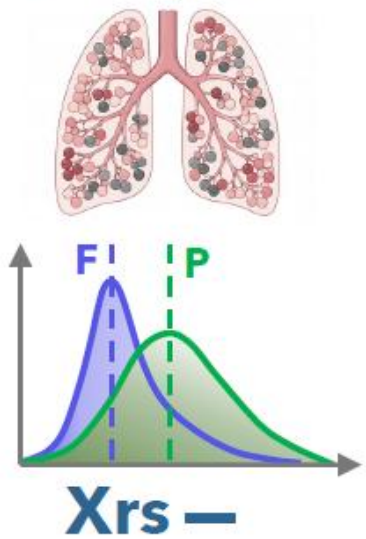
Fourier analyses
(phase shift → separate Rrs/Xrs)

Net out-of-phase pressure and flow relationship

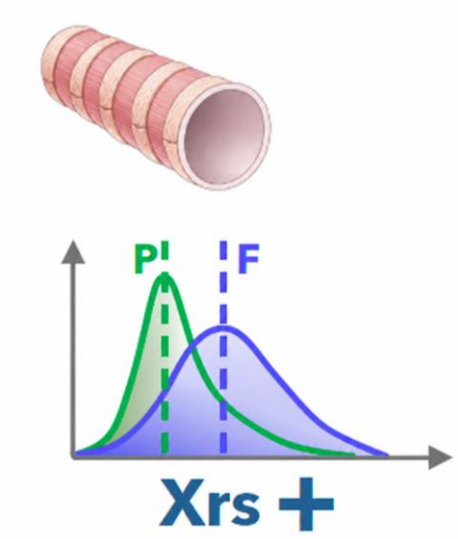




peripheral lung
@ low frequencies



central airways
@ high frequencies



IOS BDR: 제조사 기준 → 인구 기반 → Delphi 2025

출처	R5	X5	AX	근거 집단 · 비고
제조사 (Jaeger/Vyaire)[1]	−20 ~ −25%	–	−40%	Fres −20%; ΔR5−R20 −0.04 kPa·s/L
Oostveen 2013[2]	**−32%** (−0.137kPa·s/L)	**+44%** (+0.055kPa·s/L)	**−65%** (−4 cmH₂O/L)	건강 성인 368명, 95백분위, 400 µg
ERS Technical Standards 2020[3]	**−40%**	**+50%**	**−80%**	**성인 근거는 Oostveen 1편, 소아 6편** 자료 기반으로 성인·소아 동일 기준 권고; 변화 z-점수 판정은 건강인 BDR 자료 확보 후
Johansson 2021[4]	−29%	+45%	**−65%**	50–64세 무증상 1,495명, IOS, 400 µg
Jetmalani 2021[5]	−30% (−1.42 z)	+1.36 z	–	호주 ≥40세 1,145명, 6 Hz FOT, 200 µg
Thamrin 2022[6]	**−32%**	**+44%**	–	ERS 2020에서 성인 근거 부족 인정, Oostveen 95백분위를 성인 기준으로 제안
King 2024[7]	**−30%** (−1.4 z)	**+45%** (+1.4 z)	−4 cmH₂O/L	천식 전형 BDR: R5 10–20%, X5 30–50%
Chung 2025 (Delphi)[8]	**>40%** (49%)	**>50%** (49%)	**>80%** (44%)	**%변화 사용에 합의**하였으나, cut-off는 미합의, X5 Δz >1.4 합의

1. 2005 Smith HJ, ERS Monogr. 2. 2013 Oostveen E, Eur Respir J 42:1513. 3. 2020 King GG, Eur Respir J 55:1900753.
4. 2021 Johansson H, Eur Respir J 58:2100229. 5. 2021 Jetmalani K, ERJ Open Res 7:00439-2021. 6. 2022 Thamrin C, Eur Respir J 59:2102663.
7. 2024 King GG, J Allergy Clin Immunol Glob 3:100228. 8. 2025 Chung LP, ERJ Open Res 11:00398-2025.

검사 순서

① IOS	② FeNO	③ 폐활량검사	④ 기관지확장제	⑤ 폐용적 · DLCO	⑥ 기관지유발검사
평상 호흡	들숨 1회(TLC) → 호기 50 mL/s	노력성 호기 ≥3회	400 µg → 15분 → IOS → 폐활량검사	헐떡임 · TLC 흡기 · 숨참기 10 s · CO	methacholine 등
깊은 숨을 쉬기 전의 기준 상태에서 측정. 다른 검사에 영향 주지 않음.	노력성 호기가 FeNO를 일시적으로 낮추므로 폐활량검사보다 먼저	깊은 들숨이 기도 긴장도를 바꿈 → IOS·FeNO 뒤에	전후 같은 순서·같은 대기 시간	깊은 숨이 많고 기관지확장제 영향을 받고 IOS와 같이 비용 청구 불가 → 다른 날 고려	다른 날; FeNO는 유발 전에

IOS를 기도저항측정(F6009)으로 청구하는 현행 관행에서는 폐용적검사를 같은 날 시행시 IOS 비용 산정 불가
→ 폐용적검사는 다른 날 시행해야 비용 청구 가능

King GG et al. ERS technical standards for respiratory oscillometry, Eur Respir J 2020;55:1900753 (Effect of volume history; Table 1) · ATS/ERS recommendations for exhaled nitric oxide, Am J Respir Crit Care Med 2005;171:912

증례로 보는 IOS의 역할

Pre-test probability 0.3~0.7 구간에서 IOS BDR은 천식 진단에서 Post-test probability 향상

증례 1 고령, 비특이적 증상, spirometry (FEV_1 68%), BDR 음성, BPT (PC20=10.3)

증례 2 Spirometry 정상 (FEV_1 93%), BDR 음성, 메타콜린 BPT 음성

증례 3 비특이적 증상, 좌측 TB destroyed lung, FEV_1 38% (폐쇄환기장애), BDR 음성, RV 167% on DPI, bronchial distortion (BFS)

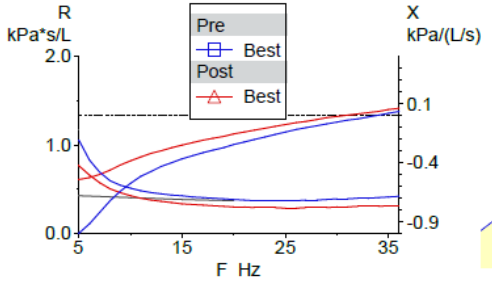
증례 1

- 78세 여성 환자. 비흡연자
- 5년 전부터 DOE mMRC 3-4, 배가 터져 나가는 것 같다. 외부병원에서 FeNO 46 ppb -> 고용량 ICS/LABA 사용하였으나 효과 없어 천식 소견이 없다고 들었다.
- 비염 - 약 알레르기 - 반려동물 - 천식 가족력 + (언니: 천식으로 사망) 야간 증상 -
- eosinophil 6.7%, eosinophil count 300/uL, PI max 42%, PE max 25%
- FeNO 54 ppb -> 28 ppb ↓
- FEV_1 70% 당시 시행한 메타콜린 BPT (PC20=10.3)
- Spirometry BDR은 음성이나, ICS/LABA/LAMA 치료 후 FEV_1 57% -> 72% ↑
- CXR: normal, Coronary CT & Echo: normal

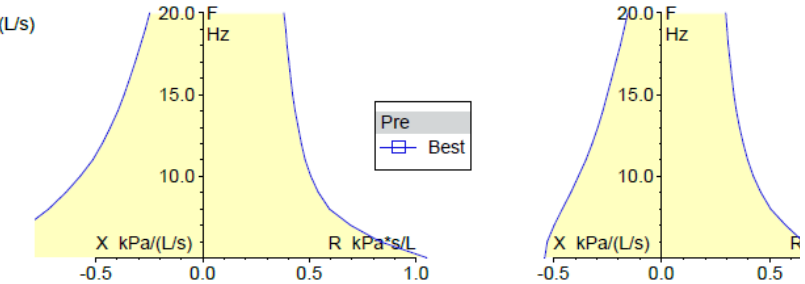
2025년 5월 / 2026년 7월 IOS

First Name:	분순	Age:	78 Years
		Height:	153 cm
Visit Date:	2025-05-14 08:50	Weight:	56.0 kg
Gender:	female	BMI:	24 kg/m²

Impulse Oscillometry Test Report

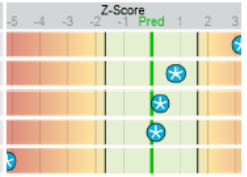


Resistance & Reactance Spectra



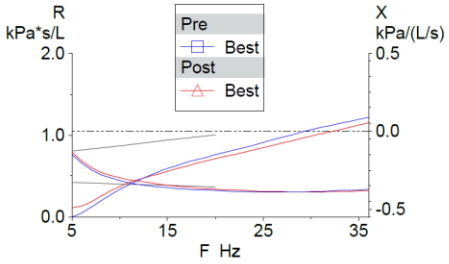
Flow-Volume-Graph

		Ref	Pre	%Pre	Post	%Post	%Chg
R5Hz	kPa/(L/s)	0.42	1.05	247.3	0.71	166.9	-32.5
R10Hz	kPa/(L/s)	0.40	0.51	125.0	0.42	104.3	-16.6
R15Hz	kPa/(L/s)	0.38	0.42	110.0	0.34	87.4	-20.6
R20Hz	kPa/(L/s)	0.36	0.38	104.6	0.30	81.7	-21.9
X5Hz	kPa/(L/s)	-0.12	-1.00	800.4	-0.40	318.0	-60.3
AX	kPa/L		9.26		4.53		-51.1

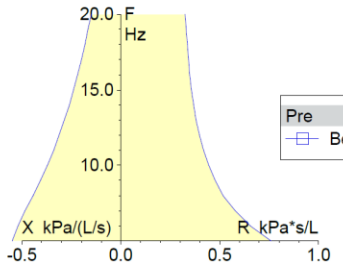


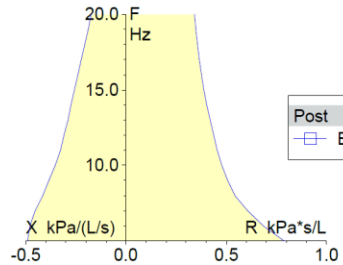
First Name:	분순	Age:	79 Years
		Height:	153 cm
Visit Date:	2026-07-06 09:36	Weight:	53.0 kg
Gender:	female	BMI:	23 kg/m²

Impulse Oscillometry Test Report



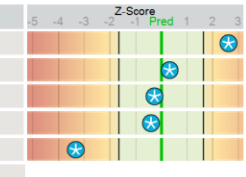
Resistance & Reactance Spectra





Flow-Volume-Graph

		Ref	Pre	%Pre	Post	%Post	%Chg
R5Hz	kPa/(L/s)	0.43	0.76	178.4	0.73	170.4	-4.5
R10Hz	kPa/(L/s)	0.41	0.44	109.5	0.47	115.3	5.3
R15Hz	kPa/(L/s)	0.39	0.36	92.6	0.39	101.2	9.3
R20Hz	kPa/(L/s)	0.37	0.32	88.6	0.34	94.2	6.4
X5Hz	kPa/(L/s)	-0.13	-0.55	433.0	-0.38	295.6	-31.7
AX	kPa/L		5.51		4.77		-13.5



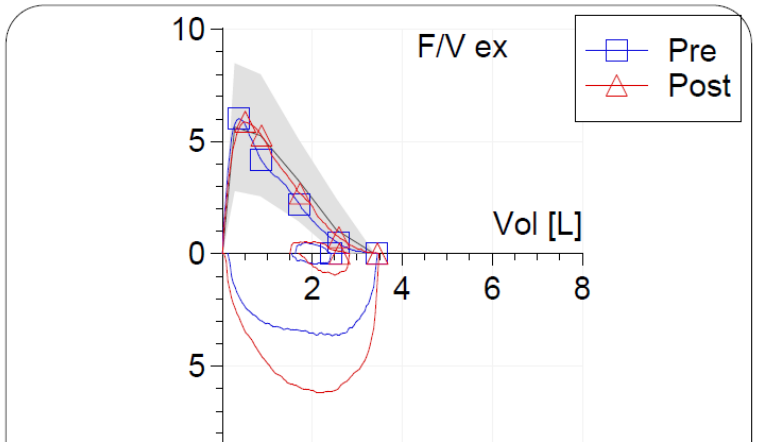
증례 2

- 61세 여성 환자. 비흡연자.
- 작년 8월 부터 에어컨 노출 후 목이 간질하면서 심한 기침 발생. wheezing - 호흡곤란 - 등산 시 가끔 숨이 안 쉬어질때가 있음.
- 1년 전 외부병원에서 천식 의심 소견으로 ICS/LABA 처방 받았으나 꾸준히 사용하지 않았으나 효과는 있었음.
- 박스 포장일 -> 먼지 많이 노출시 증상 악화.
- 비염 - 약 알레르기 - 반려동물 - 천식 가족력 - 야간 증상 -
- eosinophil 1.8% IgE 24.6 MAST: 음성, CXR: NAL, PNS: CRS
- FeNO 13 ppb, BPT 음성. Spirometry BDR 음성
- ICS/LABA 4주 이상 꾸준히 치료 후 PEFR 300 -> 400 L/min

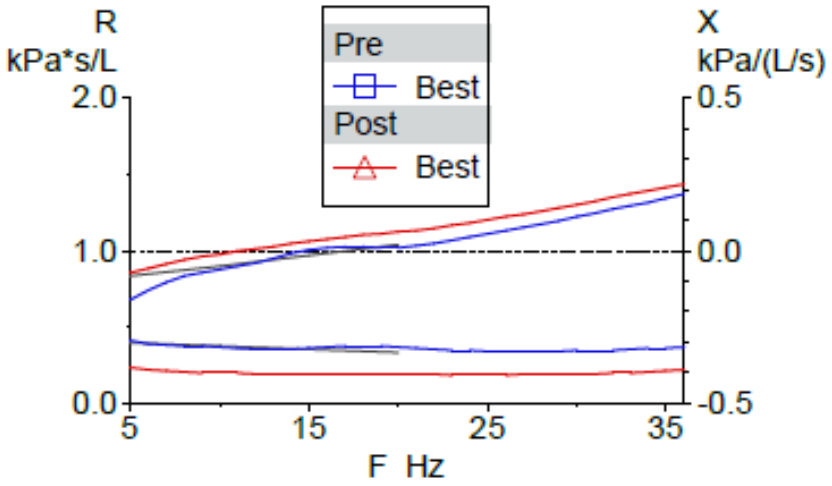
Spirometry

Gender:	female	Room:	PLM	Visit Date:	2026-07-14..	
Age:	61 Years	Race:	Asian	Physician:	나승원	
Height:	161 cm	Weight:	71.0 kg	Technician:	어운	
Any Info:	NON					

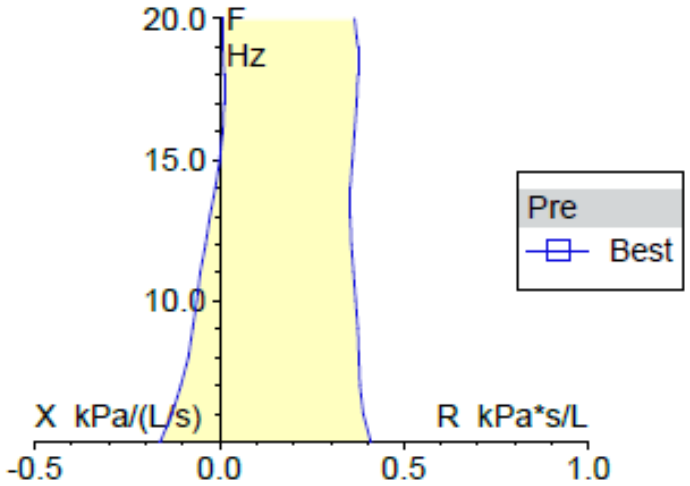
		Ref	Pre	%Ref	Post	%Ref	%Chg
SPIROMETRY							
FVC	L	3.38	3.43	102	3.45	102	0
FEV1	L	2.60	2.41	93	2.60	100	8
FEV1/FVC	%	78	70		75		
FEF25-75%	L/s	2.52	1.54	61	2.06	82	34
ISOFEF 25-75%	L/s		1.54		2.10		37
PEF	L/s	5.63	6.00	107	5.87	104	-2

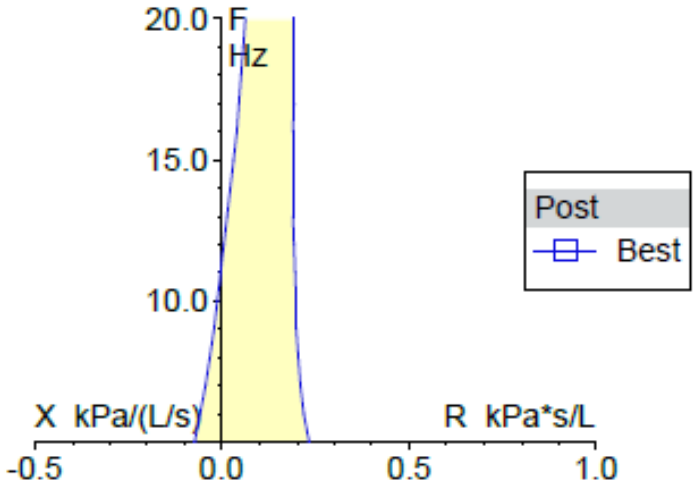


IOS



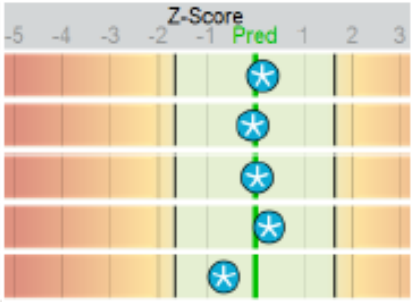
Resistance & Reactance Spectra





Flow-Volume-Graph

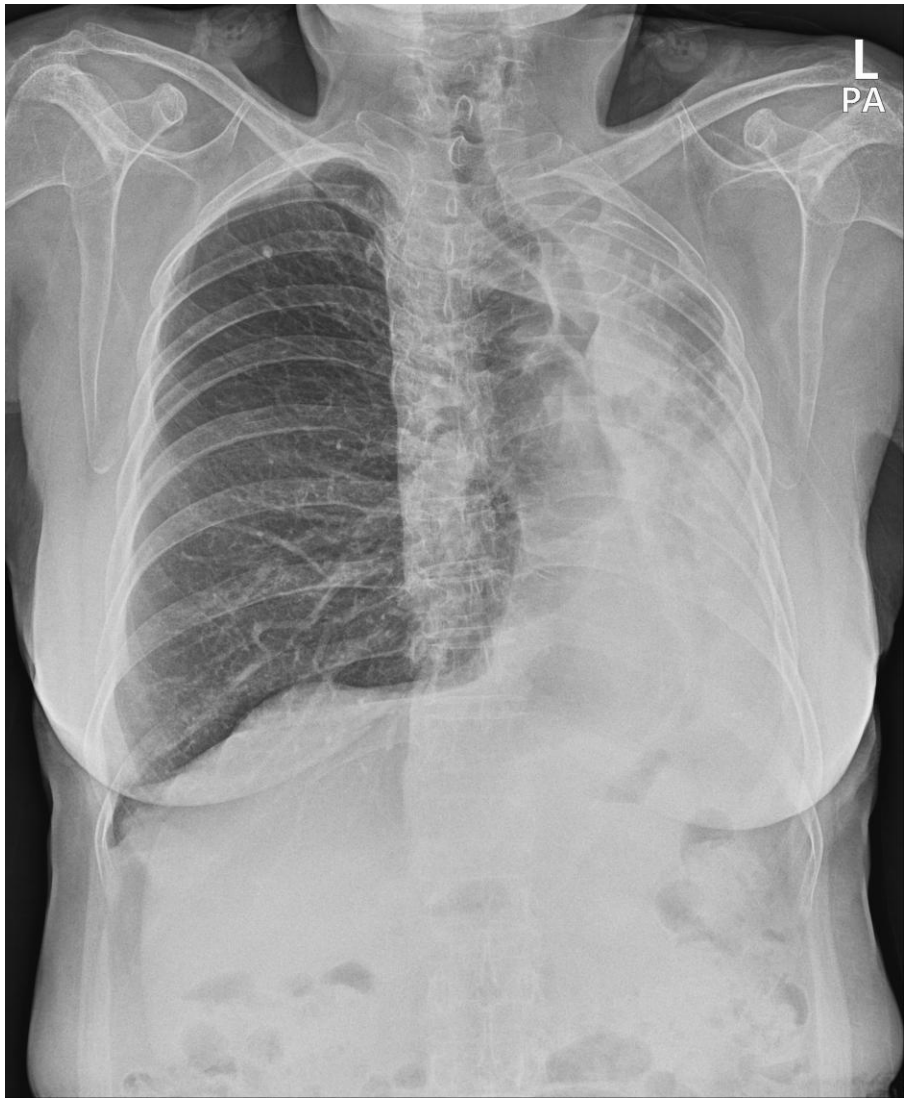
		Ref	Pre	%Pre	Post	%Post	%Chg
R5Hz	**kPa/(L/s)**	0.40	0.42	104.8	0.23	58.8	-43.9
R10Hz	**kPa/(L/s)**	0.38	0.37	98.8	0.20	52.4	-47.0
R15Hz	**kPa/(L/s)**	0.36	0.36	101.8	0.19	53.2	-47.8
R20Hz	**kPa/(L/s)**	0.34	0.37	109.2	0.19	57.4	-47.4
X5Hz	**kPa/(L/s)**	-0.08	-0.16	190.4	-0.07	86.4	-54.6
AX	**kPa/L**		0.68		0.21		-69.6

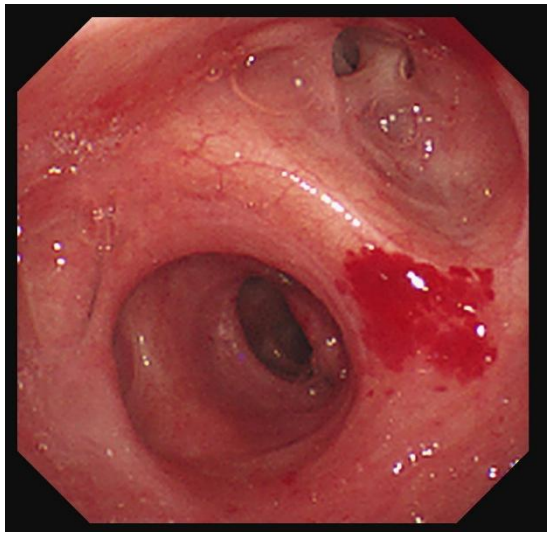


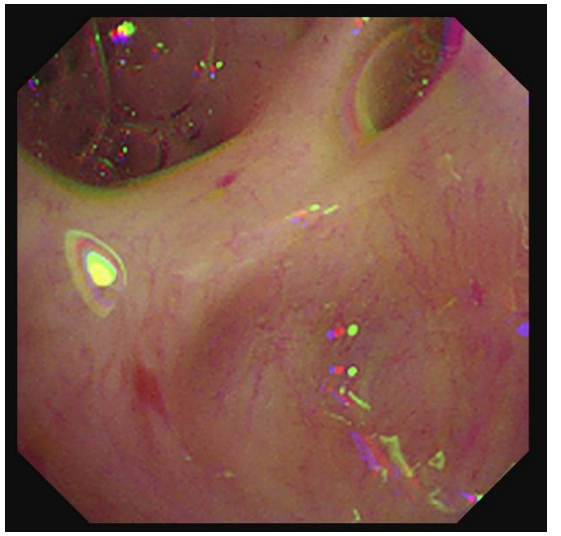
증례 3

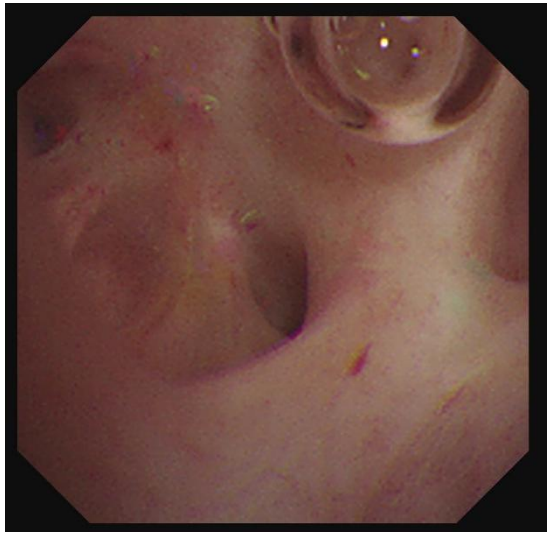
- 75세 여성 환자. 비흡연자.
- 기침/가래는 없으나 35년 전부터 움직이면 숨이 차다. mMRC 3
- 외부병원에서 천식 치료 (DPI 흡입기)하였으나 효과 없음.
- FeNO 25 ppb, CXR: Lt TB destroyed lung, PNS: normal
- BFS: Bronchial distortion and stenosis in Lt lung
- MDI 흡입기로 변경 후 FEV_1 35% -> 45% ↑, RV 167% -> 79% ↓

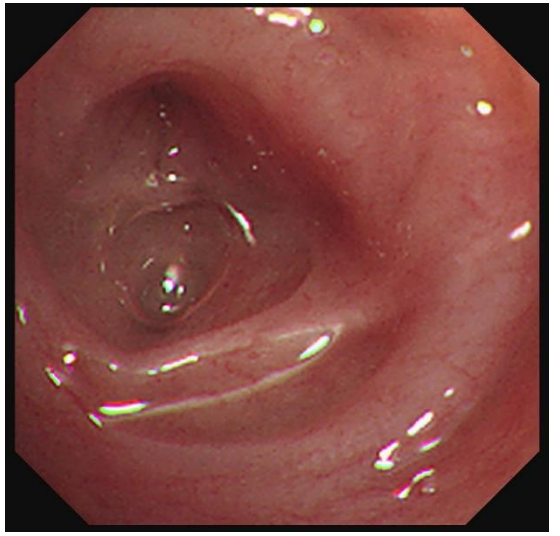
Chest X-ray & Bronchoscopy







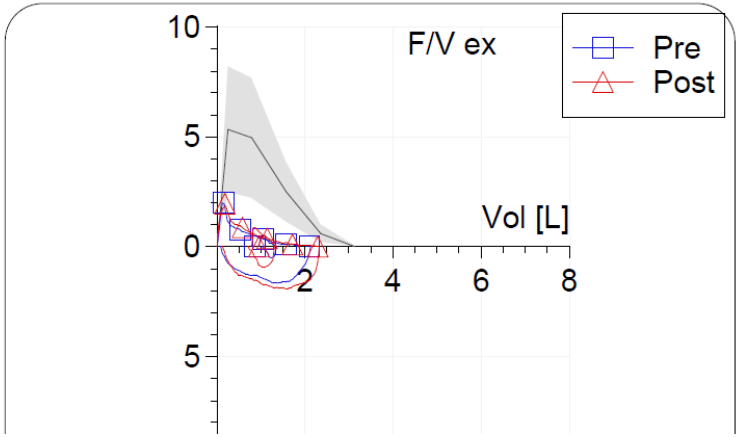




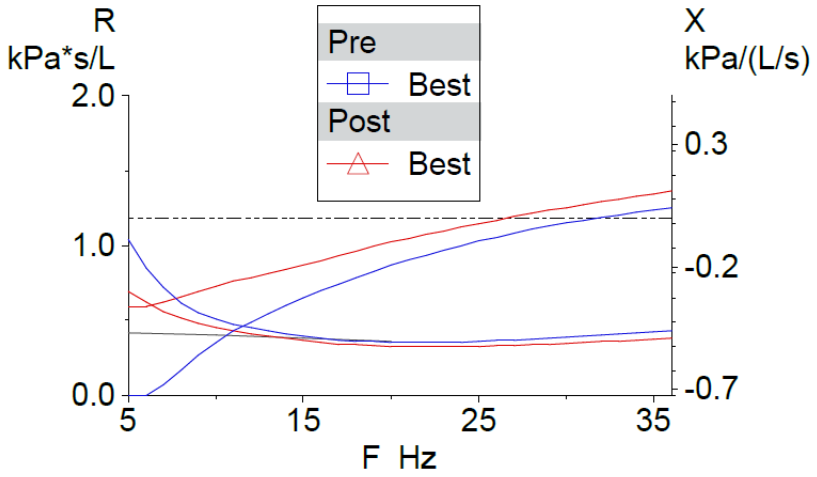
Spirometry

Gender:	female	Room:	57A	Visit Date:	2025-04-29..
Age:	75.0 Years	Race:	Asian	Physician:	나승원
Height:	162.0 cm	Weight:	65.0 kg	Technician:	어윤
Any Info:	NON				

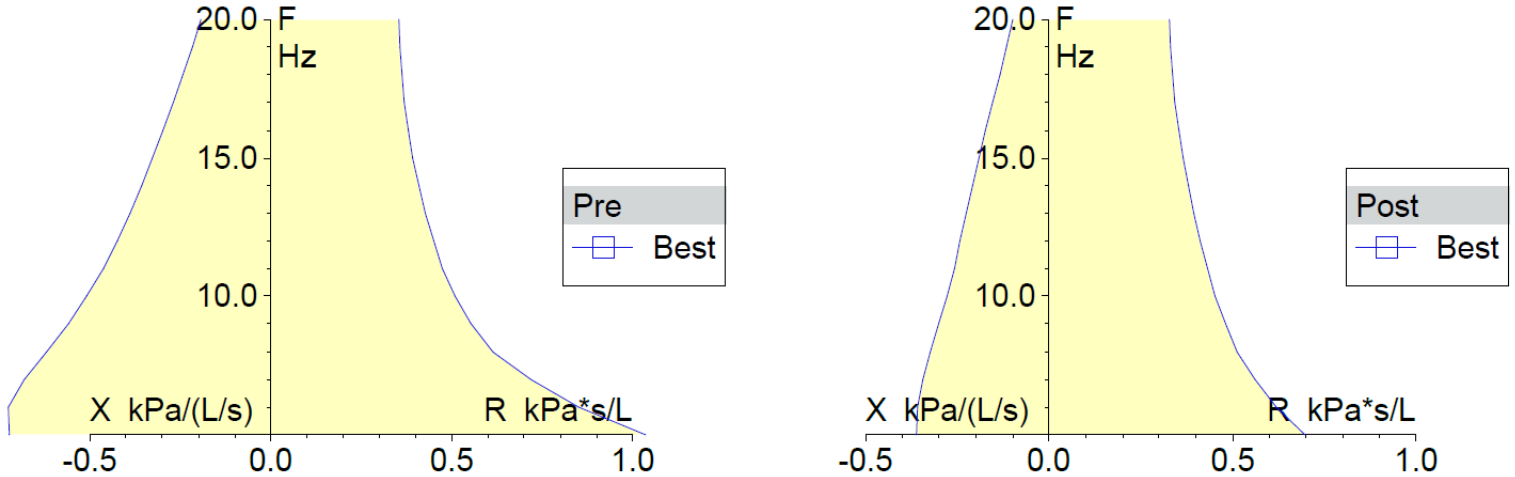
		Ref	Pre	%Ref	Post	%Ref	%Chg
SPIROMETRY							
FVC	L	3.13	2.10	67	2.29	73	9
FEV1	L	2.27	0.85	38	0.95	42	11
FEV1/FVC	%	74	41		42		
FEF25-75%	L/s	2.13	0.26	12	0.28	13	10
ISOFEF 25-75%	L/s		0.26		0.38		47
PEF	L/s	5.32	2.01	38	1.94	36	-3



IOS

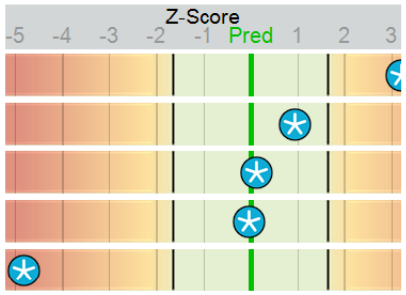


Resistance & Reactance Spectra



Flow-Volume-Graph

		Ref	Pre	%Pre	Post	%Post	%Chg
R5Hz	**kPa/(L/s)**	0.42	1.04	246.9	0.70	165.9	-32.8
R10Hz	**kPa/(L/s)**	0.40	0.51	127.3	0.45	113.4	-10.9
R15Hz	**kPa/(L/s)**	0.38	0.39	103.5	0.36	96.2	-7.0
R20Hz	**kPa/(L/s)**	0.36	0.36	98.9	0.33	91.3	-7.7
X5Hz	**kPa/(L/s)**	-0.12	-0.72	615.7	-0.36	308.0	-50.0
AX	**kPa/L**		7.55		3.86		-48.8



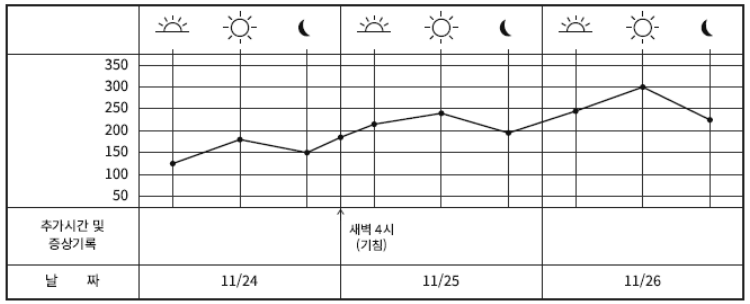
FX661 (2,670원) 최고호기유량측정(휴대용) [1일당]

✶ 최대호기유속 측정 처방시 최대호기유속기 사용법은 폐기능검사실로 교육 의뢰합니다.
5PM 이후와 주말 처방은 담당간호사가 다음과 같이 교육하고, 정규시간에 재교육 의뢰합니다.

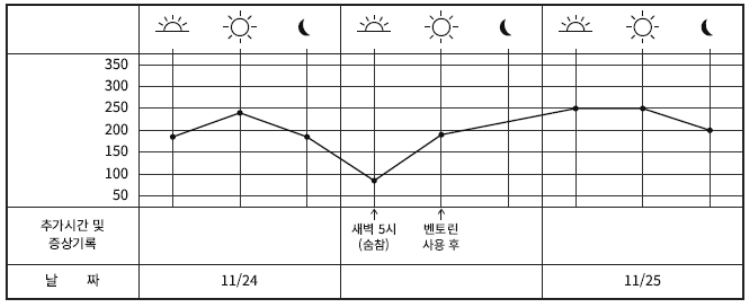
【최대호기유속기 사용법 및 기록표 작성요령】

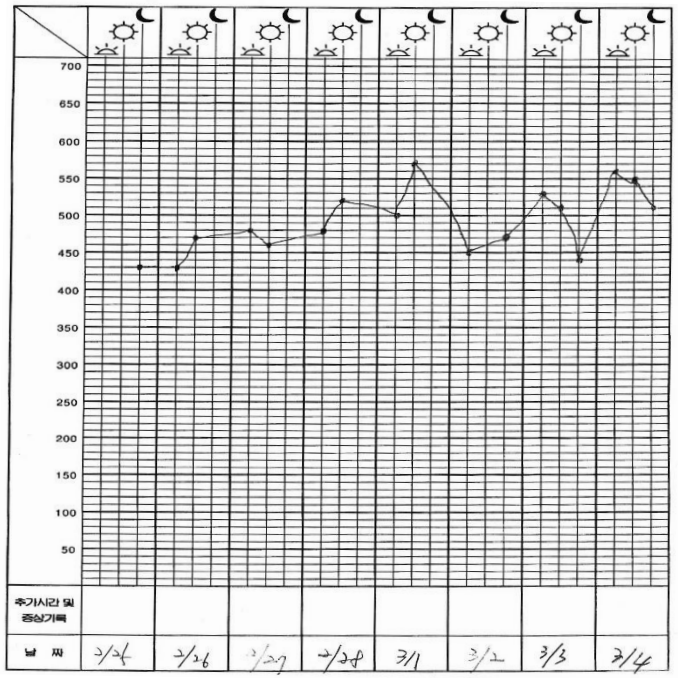
1. 먼저 측정기의 눈금 부분에 있는 표식을 최대한 아래로 내리십시오.
2. 한손에 측정기를 수평으로 든 상태에서 입을 크게 벌리고 숨을 깊게 들이마십니다.
3. 측정기의 입구를 재빨리 입에 대고 입을 잘 다문 후 혀가 측정기의 입구를 막지 않도록 주의하면서 최대한 힘껏 짧고 세게(촛불을 끄듯이) 붑니다.
4. 이와 같은 방법으로 표식이 움직여 일정한 눈금을 가리키면 그 수치를 확인하십시오.
5. 이상과 같은 방법으로 하루에 2회(아침, 저녁) 또는 3회(아침, 점심, 저녁), 흡입기 사용 전에, 1회에 3번 최대호기유속을 측정하셔서 그 중 제일 높은 수치 하나를 최대호기유속 기록표에 기록하십시오.

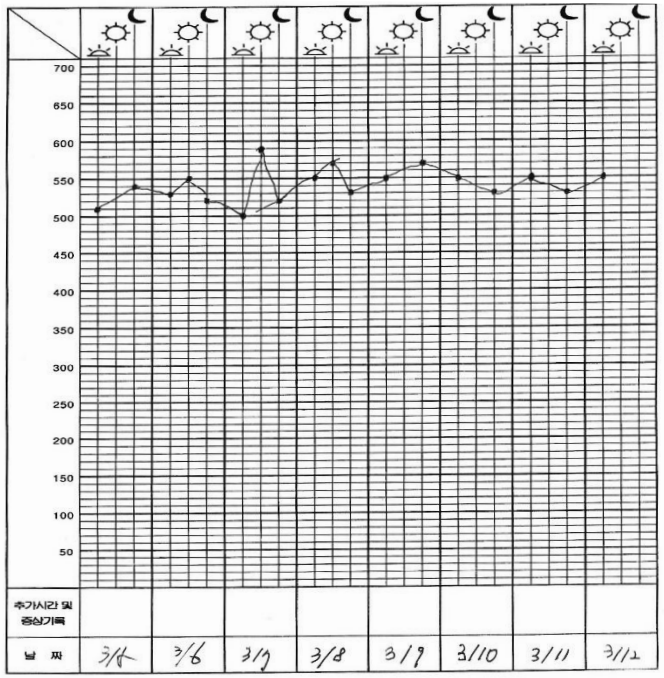
<예 1> 기침이나 증상 발생 시 기록하세요.

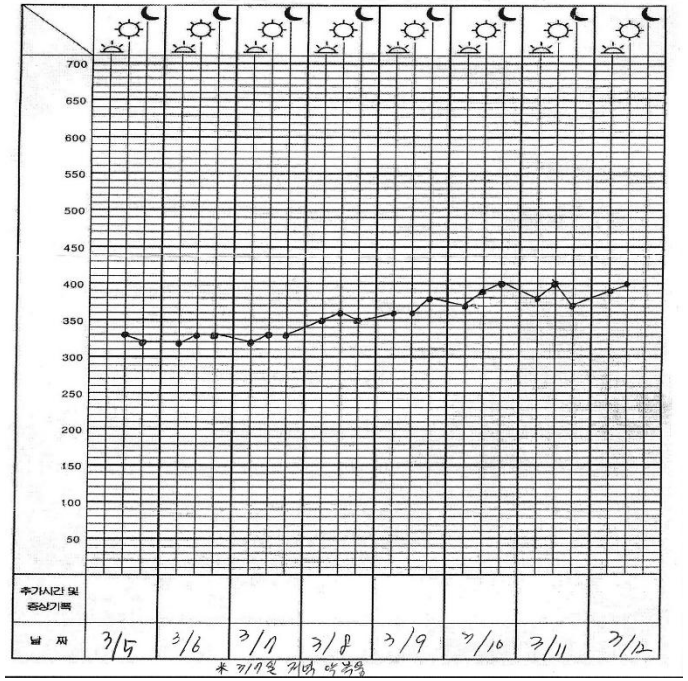


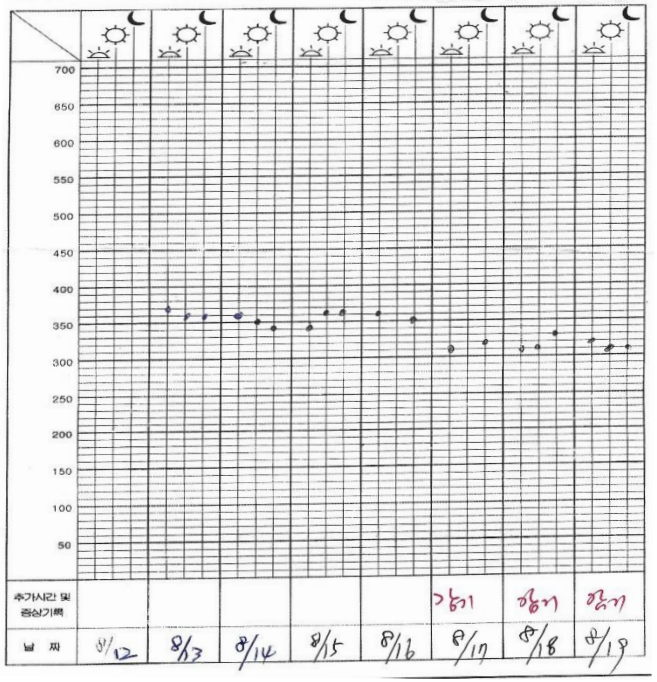
<예 2> 만약 하루 3회 외에 호흡곤란으로 속효성 기관지확장제 (벤토린 등)을 사용해야 할 경우에는 흡입제 사용 전과 사용 후 15분이 경과한 후 각각 추가로 검사하시고 기록하여 주십시오.







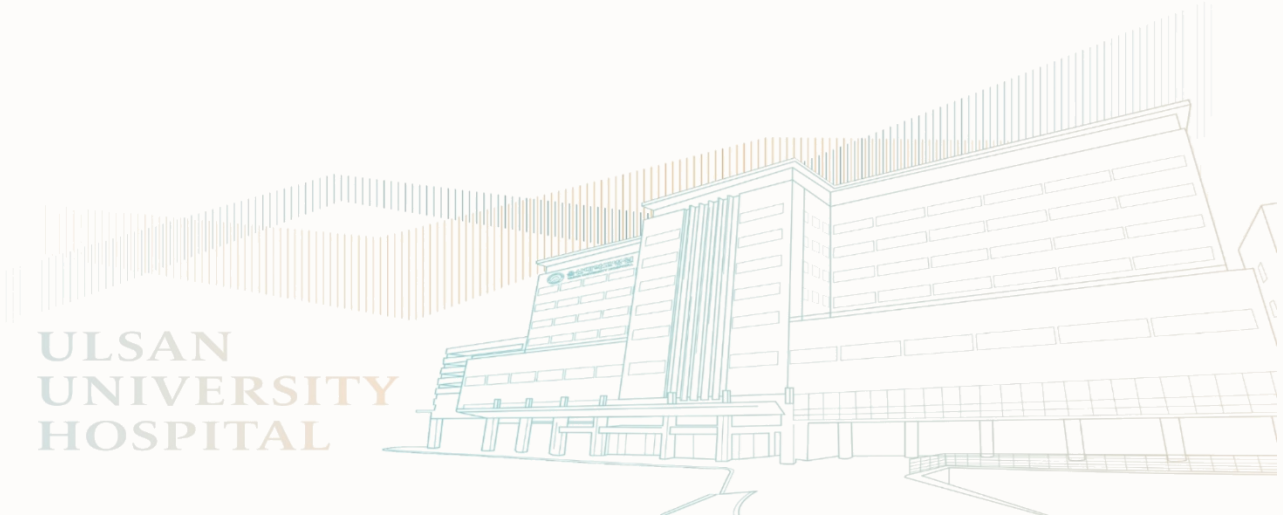




요약: IOS 검사 후 천식 진단 확률

- **사전검사확률에서 사후검사확률**
  - 유병률/사전검사확률이 낮으면 검사 양성시 천식 확률 낮아지고 (Bayes), 음성시 천식 배제 어렵다.
  - 민감도·특이도는 검사 선택용, LR은 유병률과 무관 → 행동 역치까지 확률 shifting
- **폐기능검사 측정 지표 차이**
  - 폐활량검사는 유량·용적 (노력 의존, 압력·저항 없음), 체적변동기록법은 기도저항만 (Raw)
  - IOS → 평상호흡 중 압력과 유량을 동시 측정 → 노력 비의존, 저항과 리액턴스 (관성/탄성)
- **IOS: Negative frequency dependency & 시간상수 (τ)**
- R20 = 중심 기도, R5 = 전체 저항 → R5–R20은 소기도 질환 지표
  - X5↓(더 음수), Fres↑, AX↑ = 섬유화/비만/흉벽/흉막질환, 갇힌 공기, 소기도 질환
- **IOS 검사의 천식진단에서 보완적인 역할**
  - FEV_1 정상·BDR 음성인 환자에서 IOS BDR과 말초 지표가 사후확률을 더 올려 준다
  - IOS BDR 기준 제안: 기저치 대비 %변화, **R5 -30%, X5 +45%, Ax -65%**

경청해 주셔서 감사합니다



환기장애의 분류

	TLC	RV	VC	FEV_1/FVC	MIP	MEP
폐쇄성 환기장애	N to ↑	↑	↓	↓	N	N
제한성 환기장애						
Pulmonary parenchymal	↓	↓	↓	N to ↑	N	N
Extraparenchymal - inspiratory	↓	N to ↓	↓	N	↓/N*	N
Extraparenchymal – inspiratory + expiratory	↓	↑	↓	Variable	↓/N*	↓/N*

*Reduced if due to respiratory muscle weakness; normal if due to chest wall stiffness.

제한성 환기장애 – Extraparenchymal 유형별 특징

- **흡기만 장애** (흡기근 약화, 흉벽 경직, 비만) → **MIP ↓, RV는 대개 유지**
- **흡기 + 호기 장애** (호기근 약화, 흉벽 변형) → FRC 이하에서 흉곽이 rigid → **RV ↑, MEP ↓**
- **신경근 질환(NM disease)**은 흡기·호기 모두 장애 → **RV ↑, TLC ↓** 형태