SPIROMETRY

From Physiological Principles to Clinical Interpretation

Dr S. Sadeghi
Associate Professor of Pulmonology
Isfahan University of Medical Sciences

Learning objectives

SPIROMETRY | PHYSIOLOGY → MEASUREMENT → CLINICAL DECISIONS

01 Explain what spirometry measures—and what it cannot measure

02 Relate FEV_1, FVC and flow–volume curves to respiratory mechanics

03 Recognize technically unacceptable maneuvers and assess test quality

04 Interpret obstructive, possible restrictive and nonspecific patterns

05 Apply bronchodilator-response criteria and integrate results with clinical context

Spirometry: a dynamic measurement of ventilatory function

Measures

Airflow and exhaled / inhaled volume during breathing maneuvers

Does not directly measure

Residual volume (RV), functional residual capacity (FRC), or total lung capacity (TLC)

Clinical role

Detects ventilatory patterns; supports diagnosis, grading, monitoring and risk assessment

Key distinction

A low FVC is not synonymous with restriction. Restriction requires a reduced TLC.

Think of spirometry as a forced, time-dependent maneuver—not a direct image of lung structure.

Physiological foundations: why does the curve look this way?

Elastic recoil

At high lung volume, elastic recoil and airway caliber support high expiratory flow.

Airway resistance

Small changes in airway radius can markedly alter resistance and expiratory flow.

Dynamic compression

During forced expiration, pleural pressure may exceed airway pressure downstream of the equal-pressure point.

Effort dependence changes

Early expiration: peak flow is strongly influenced by effort. Mid-to-late: flow becomes limited by recoil and airway mechanics.

Core spirometric indices

FVC

Forced vital capacity

Total volume forcibly exhaled after full inspiration.

FEV_1

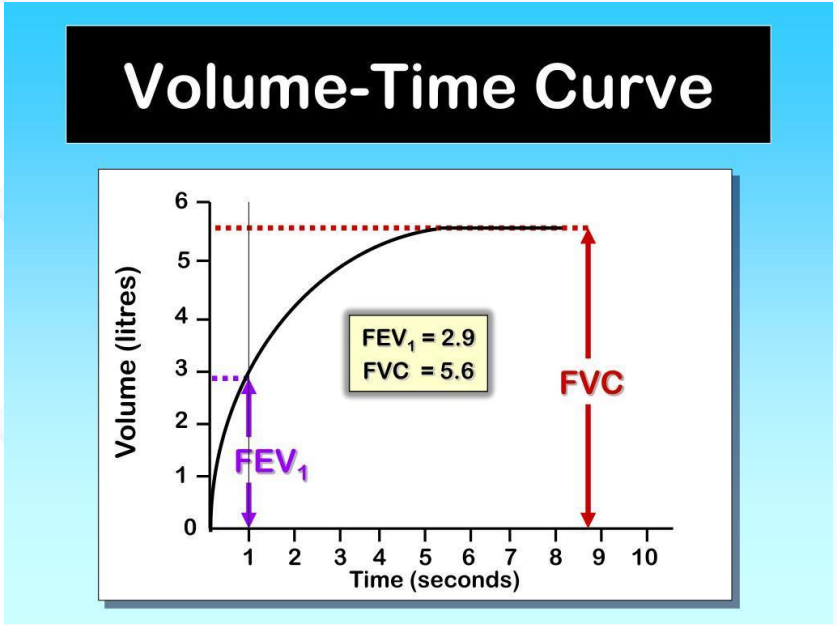
Forced expiratory volume in 1 s

Volume exhaled in the first second of the FVC maneuver.

FEV_1/FVC

Ratio

Key index for airflow obstruction.



Also useful: PEF (effort-dependent), $FEF_{25–75}$ (variable, not stand-alone), and the flow–volume loop for pattern recognition.

The forced vital capacity maneuver: coach the sequence

1

Prepare

Seated upright; nose clip; tight lip seal; explain and demonstrate.

2

Inhale fully

Rapid maximal inspiration to TLC; pause ≤2 seconds.

3

Blast out

Explosive start; continue expiration maximally and without hesitation.

4

Finish + inhale

Continue to end of expiration; then inspire maximally if using an inspiratory loop.

Coaching is part of the measurement.

Use short, energetic cues: "Big breath in… BLAST… keep going… keep going… all the way out."

Quality control: acceptability before interpretation

Within-maneuver checks

- Full inspiration before the blow
- Satisfactory start: back-extrapolated volume ≤5% of FVC or 0.100 L
- No cough in the first second for FEV_1
- No leak, mouthpiece obstruction or glottic closure
- Adequate end of forced expiration

Between-maneuver repeatability

In adults and children >6 years:

- Difference between the two largest FEV_1 values ≤150 mL
- Difference between the two largest FVC values ≤150 mL

Aim for ≥3 acceptable maneuvers; usually no more than 8 attempts in adults.

Recognize common technical errors

Hesitant start

Low / distorted early flow; inspect back-extrapolated volume

Cough in first second

May invalidate FEV_1

Early termination

Falsely low FVC; absent/short terminal plateau

Leak or poor seal

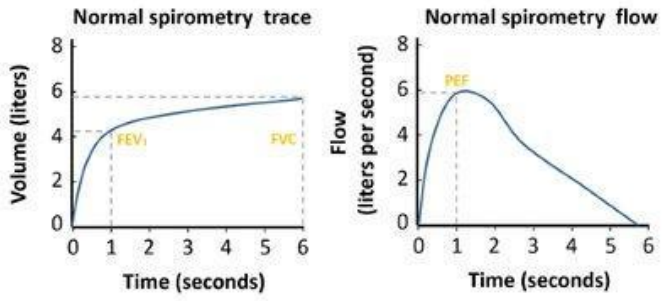
Unreliable volume and flow

Submaximal inspiration

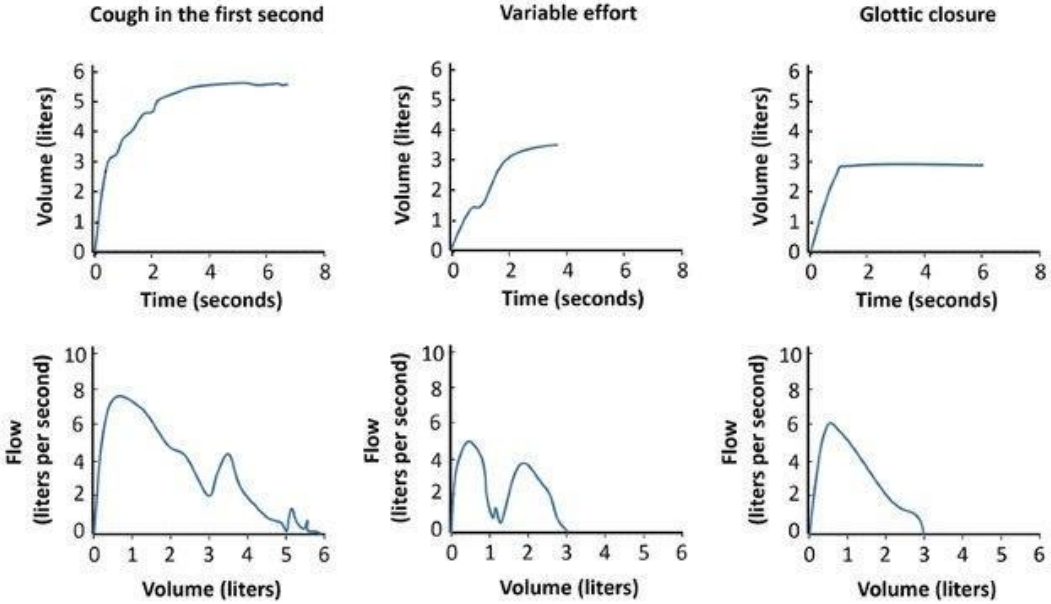
Both FEV_1 and FVC may be underestimated

Glottic closure / Valsalva

Abrupt interruption of flow



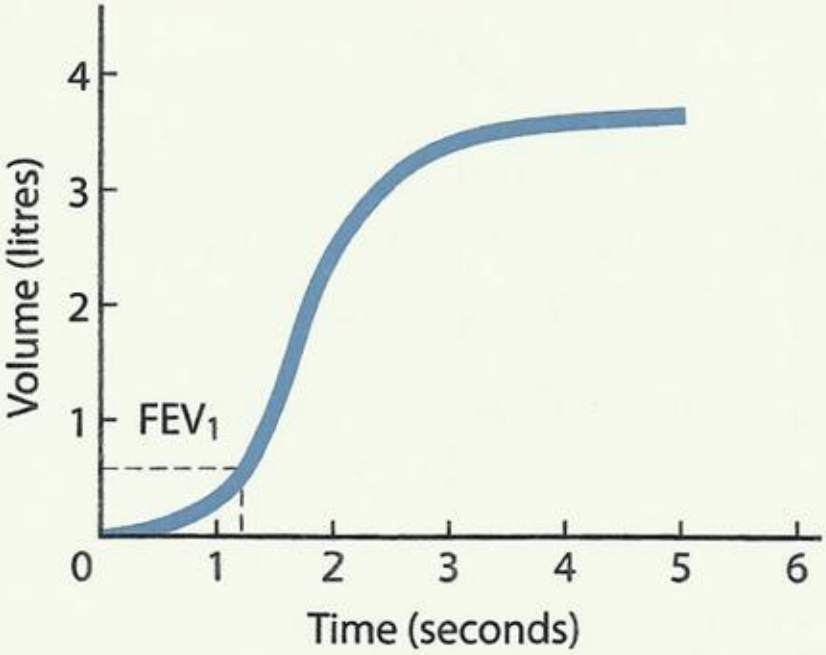
a)

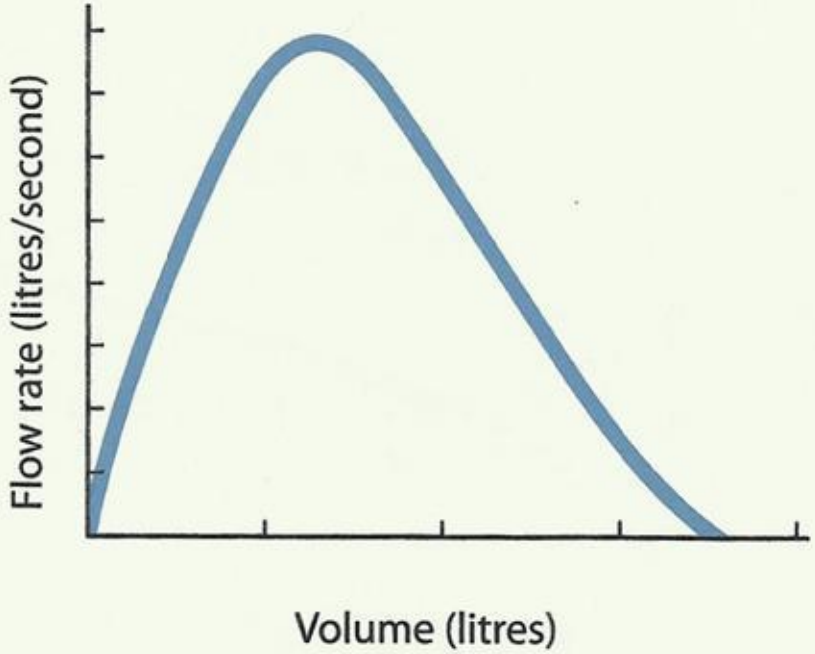


b)

Made with GAMMA

FIGURE 3. SLOW START





Made with GAMMA

Read the flow–volume loop in three steps

1

Shape

Expiratory limb above the axis; inspiratory limb below it.

2

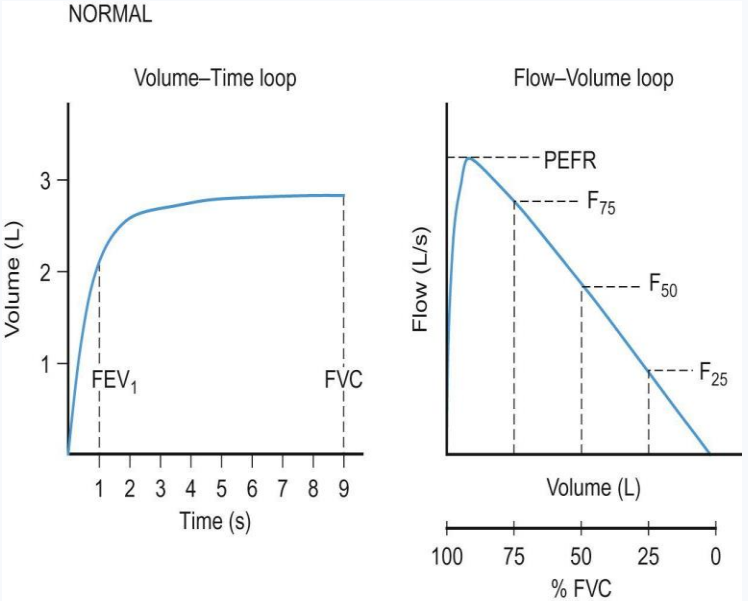
Peak and contour

Peak expiratory flow, then the descending limb; look for concavity or flattening.

3

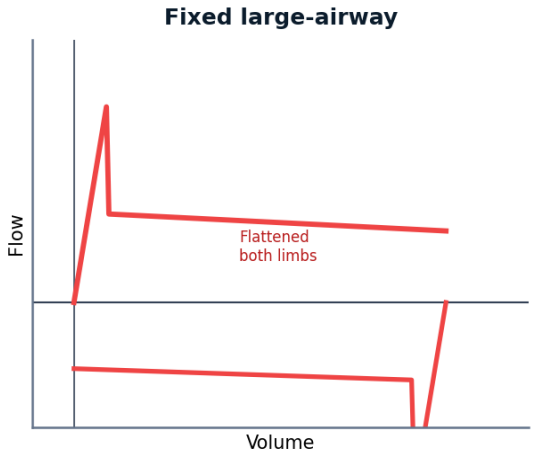
Volume and symmetry

Assess overall width, loop closure and inspiratory limb.



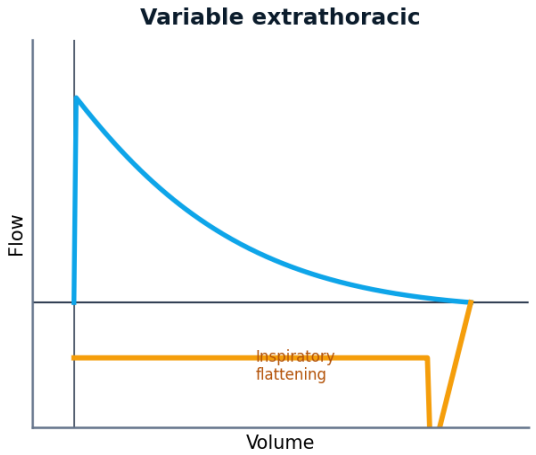
Normal flow–volume loop

Flow–volume loops can reveal upper-airway obstruction



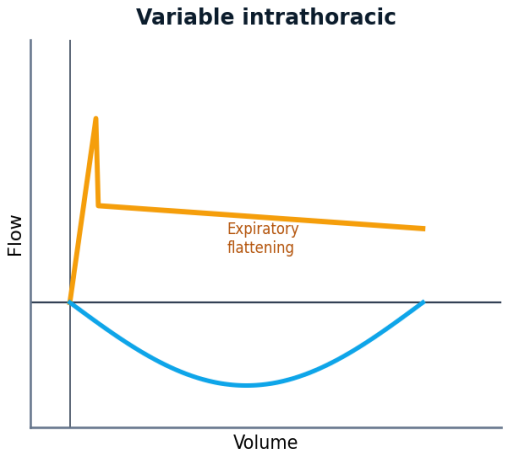
Fixed large-airway

Flattening of both inspiratory and expiratory limbs.



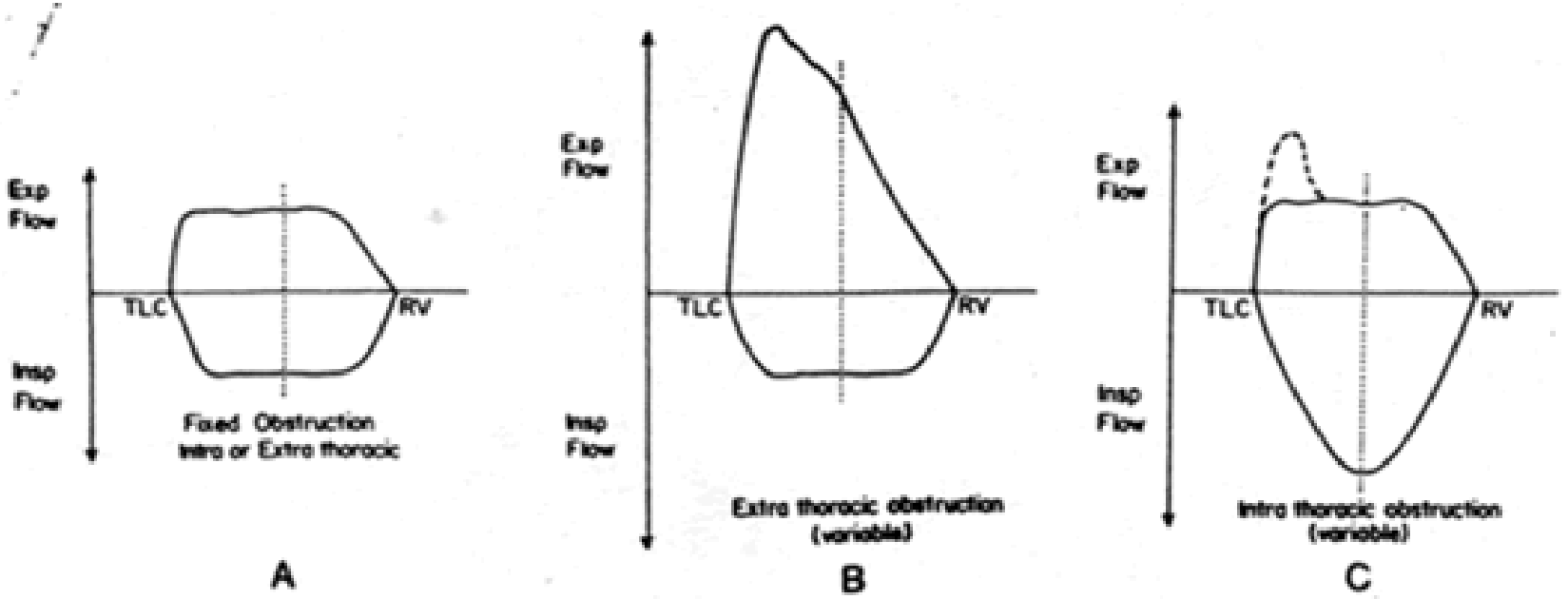
Variable extrathoracic

Predominant inspiratory flattening; e.g. vocal cord dysfunction / ILO.

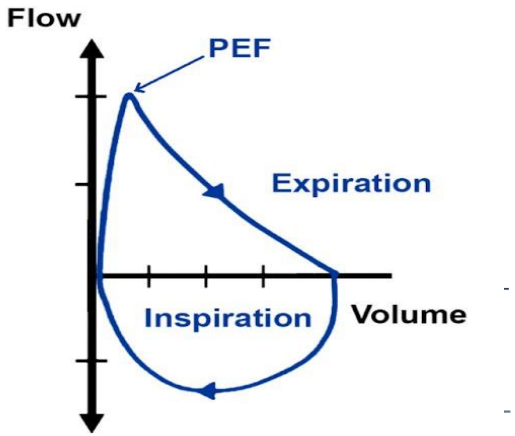


Variable intrathoracic

Predominant expiratory flattening; consider central-airway disease.

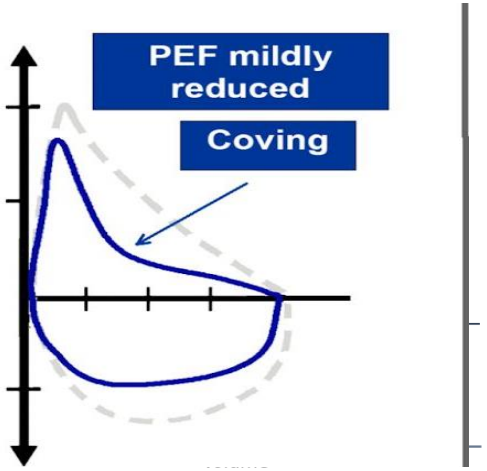

Exp Flow
Insp Flow
TLC
RV
Fixed Obstruction
Intra or Extra thoracic
A
Exp Flow
Insp Flow
TLC
RV
Extra thoracic obstruction
(variable)
B
Exp Flow
Insp Flow
TLC
RV
Intra thoracic obstruction
(variable)
C

Classic patterns: normal, obstructive and small-volume



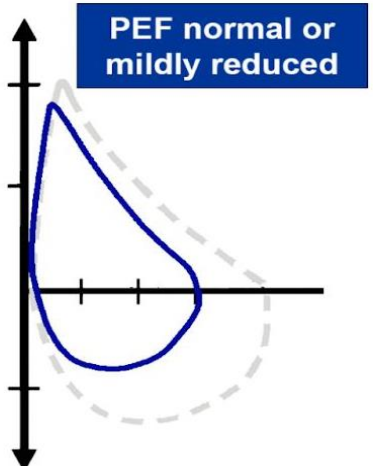
Normal

Preserved ratio;
FEV_1 and FVC within expected range



Obstructive

Low FEV_1/FVC;
expiratory concavity is common



Possible restriction

Low FVC with preserved / high ratio;
confirm TLC

Obstruction: start with the ratio

FEV_1/FVC below the lower limit of normal (LLN)

Physiological meaning

A disproportionate reduction in early expiratory flow relative to the total forced vital capacity.

Common contexts

Asthma, COPD, bronchiectasis and other diseases causing airflow limitation.

Do not overcall

A fixed 0.70 threshold can misclassify younger and older adults; use age-appropriate LLN / z-scores.

Low FVC: restriction, air trapping—or poor technique?

True restriction

Low FVC + preserved / high FEV_1/FVC; TLC below LLN confirms restriction.

Air trapping

Obstruction with premature airway closure can reduce FVC (“pseudo-restriction”); RV/TLC may be high.

Suboptimal effort

Incomplete inspiration or early termination can artifactually lower FVC.

Clinical rule: spirometry suggests restriction; lung-volume measurement confirms it.

When the pattern is mixed or discordant, measure TLC and RV (plethysmography or gas dilution as appropriate).

Bronchodilator responsiveness: quantify the change

2022 ERS/ATS interpretive standard

Positive bronchodilator response: increase in FEV_1 or FVC >12% of the predicted value.

Calculation

(Post-BD value − Pre-BD value)
÷ predicted value × 100

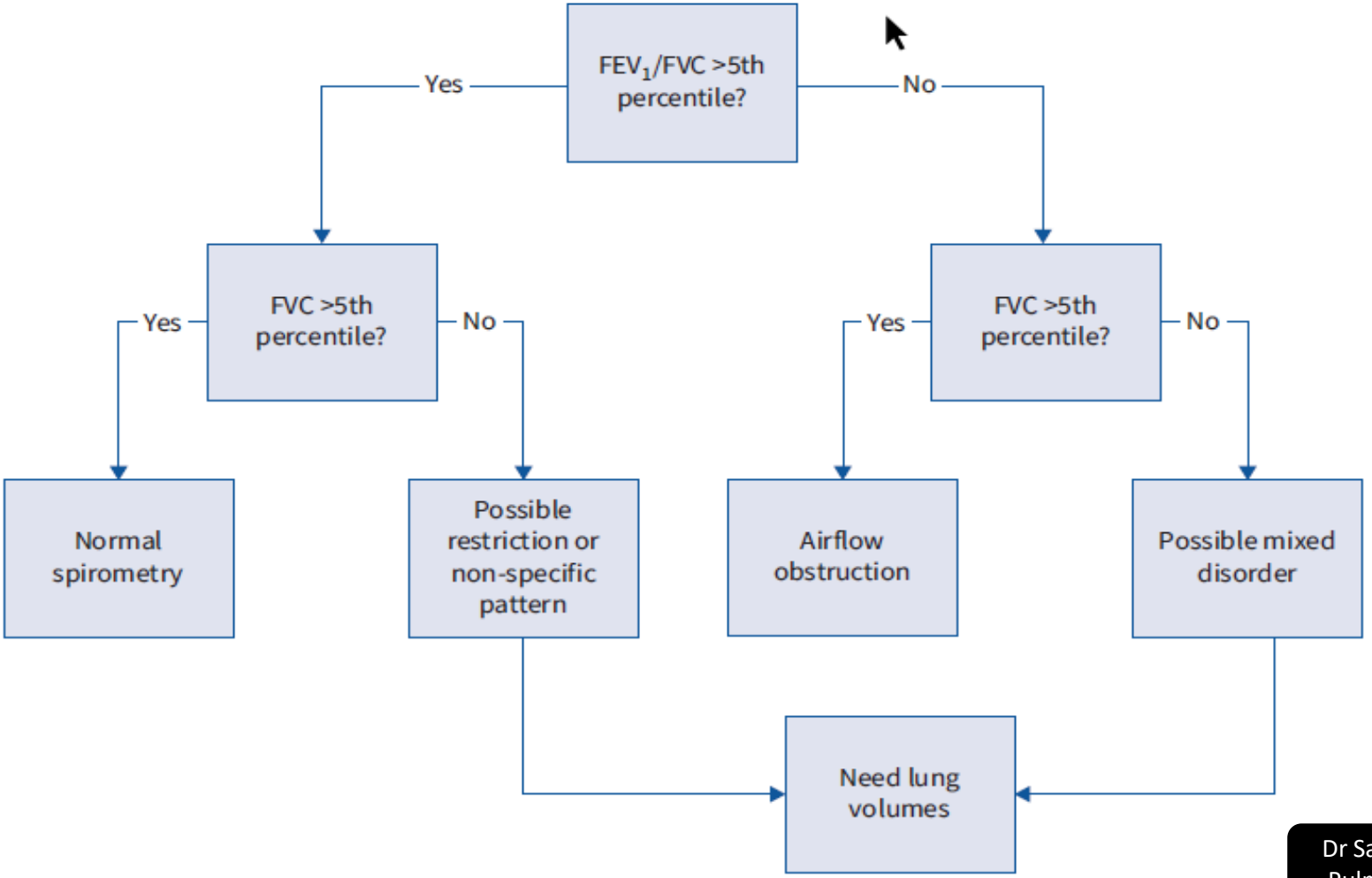
Example

Predicted FEV_1 = 3.0 L; pre = 1.80 L; post = 2.15 L
Change = 0.35 L ÷ 3.0 L × 100 = 11.7%

A positive response does not by itself diagnose asthma; absence of response does not exclude it.

A practical interpretation algorithm

1. **Check test quality**
   Acceptability, repeatability and clinical plausibility
2. **Classify the ratio**
   FEV_1/FVC below LLN? → airflow obstruction
3. **Assess FVC**
   If low with preserved ratio → consider restriction; confirm TLC
4. **Grade impairment**
   Use FEV_1 / FVC z-scores and reference limits
5. **Integrate context**
   Symptoms, exposure, imaging, prior tests and response to therapy



Dr Sadeghi, MD
Pulmonologist

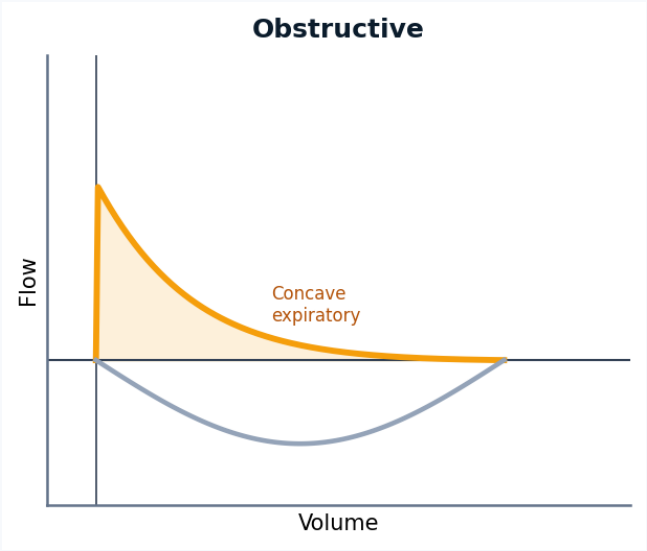
Case 1: is this airflow obstruction?

A 58-year-old with chronic cough and 35 pack-years

FEV_1	FVC	FEV_1/FVC
1.65 L	**2.80 L**	**0.59**
58% predicted	78% predicted	LLN = 0.66

Interpretation

Obstructive ventilatory impairment.
Next: assess severity, symptoms and exacerbation risk.



Schematic obstructive pattern

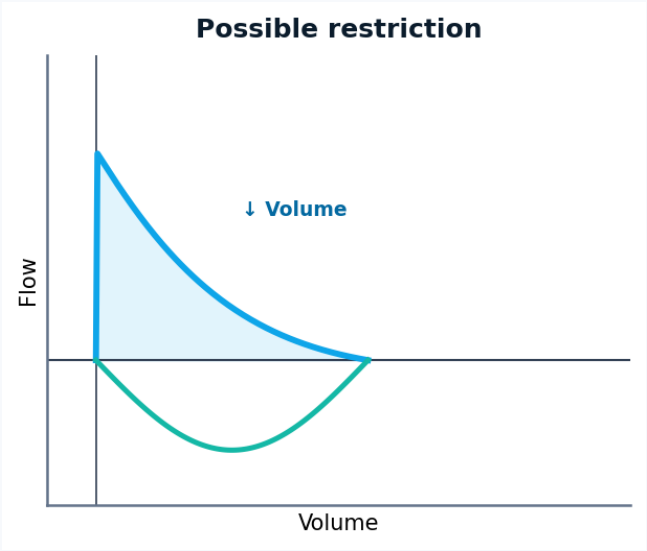
Case 2: does a low FVC prove restriction?

A 42-year-old with exertional dyspnea

FEV_1	FVC	FEV_1/FVC
2.05 L	**2.45 L**	**0.84**
68% predicted	65% predicted	LLN = 0.72

Interpretation

Preserved ratio with low FVC.
Next: measure TLC; check test quality and clinical context.



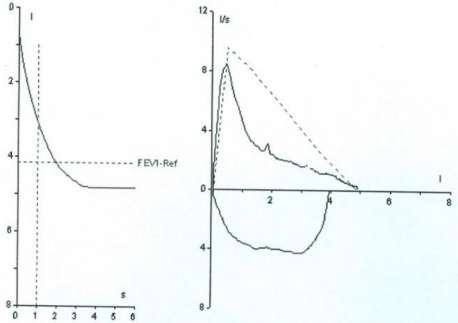
Schematic small-volume pattern

Alzahra Hospital
Respiratory Clinic
Esfahan - Iran
Tel. +98 (311) 625-5555

Doosti, Fereydoon
ID-Nr: 000000012100
Comment:
Treating Doctor:
Referring Doctor:
Annotations:

175 cm, 85 kg, male *01.01.1988 =30Y
Test: 19.04.2018 / 09:21 h
Station:
Smoking Habits: Cig/Day Years

Spirometry: Flow-Volume



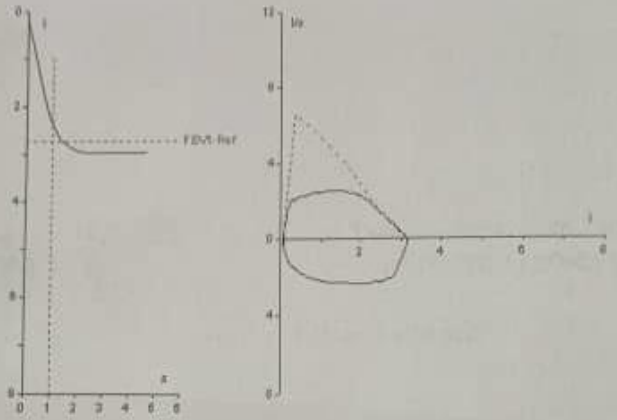
parameter	unit	pred	act.	%pred
FVCex	l	4.96	4.94	100
FEV1	l	4.17	3.05	73
FEV1/FVC	%	82	62	75
PEF	l/s	9.60	8.48	88
MEF75	l/s	8.22	3.45	42
MEF50	l/s	5.35	2.02	38
MEF25	l/s	2.45	1.15	47
MEF25-75	l/s	4.81	1.93	40
Aex	l*l/s		13.19	

Comment:

© 2008 nSpire Health GmbH Germany Tel: +49 9736 8181-0

Test: 19.04.2018 / 09:21
BTPS: 21 / 1013 / 20 [°C / mbar / %]

Spirometry: Flow-Volume



parameter	unit	pred	act.	%pred
FVCex	l	3.19	3.10	97
FEV1	l	2.74	2.88	105
FEV1/IVC	%	81		
FEV1/FVC	%	81	93	115
PEF	l/s	6.53	5.24	80
MEF75	l/s	5.75	2.40	42
MEF50	l/s	4.05	2.51	62
MEF25	l/s	1.72	1.68	97
MEF25-75	l/s	3.46	2.33	67
Aex	l*l/s		5.85	

Comment:


a

Case 8

Spire ZAN

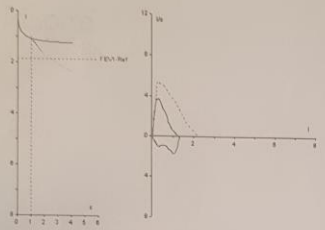
Alzahra Hospital
Respiratory Clinic
Esfahan -IRAN
Tel. +98(31) 36255555

Darabi, Roghieh
ID-Nr: DarRog010167
Comment:

148 cm, 59 kg, female *01.01.1967 =55Y
Test: 20.09.2022 / 22:17 h

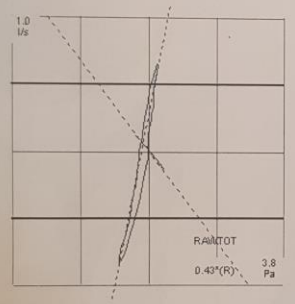
L4/C4

Lungfunction: Summary



Spirometry and Flow-Volume :

parameter	unit	pred	act.	%pred
VC	l	2.19	1.38	63
IC	l	1.64	0.58	35
FVCex	l	2.24	1.33	60
FEV1	l	1.87	1.17	62
FEV1/IVC	%	79	85	108
FEV1/FVC	%	79	88	112
PEF	l/s	5.38	3.74	69
MEF75	l/s	4.99	3.68	74
MEF50	l/s	3.41	2.22	65
MEF25	l/s	1.29	0.59	46
MEF25-75	l/s	2.90	1.55	53



Resistance :

RAWtot	kPa/(l/s)	0.30	0.43	144
sRAWtot	kPa*s	0.71	0.69	97

Volumes :

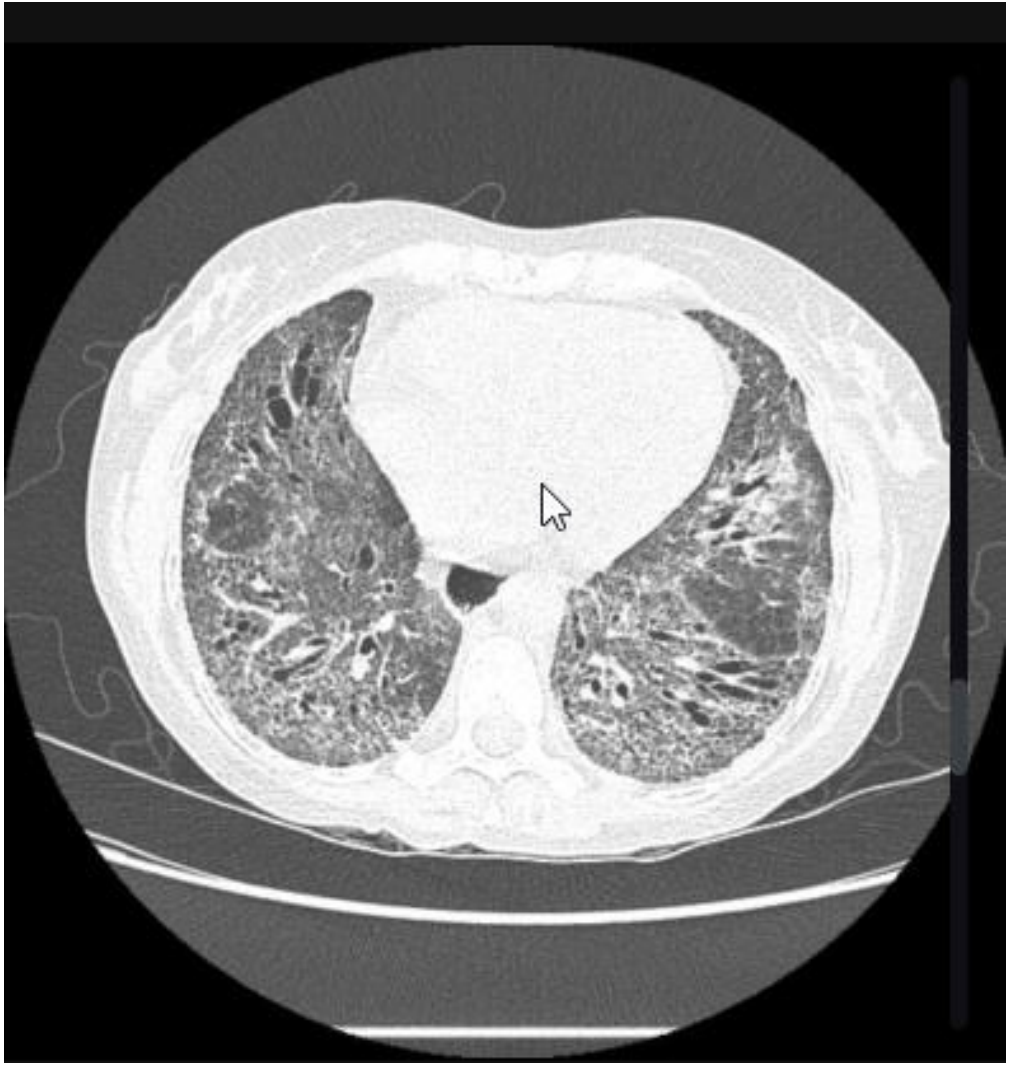
TGV	l	2.37	1.59	67
TLC	l	3.98	2.35	59
VC	l		1.38	
RV	l	1.56	0.97	62
TGV/TLC	%	54	68	126
RV/TLC	%	38	41	110

CO Diffusion :

parameter	unit	pred	act.	%pred
TLco(Hb)	mmol/kPa/min	6.66	3.98	60
Kco(Hb)	mmol/kPa/min/l	1.67	1.41	84

file://C:\ZAN\REPSRV\temp\a0.htm

9/20/2022



Practical and clinical pearls

- Never interpret numbers before reviewing the curves and quality grade.
- Use LLN / z-scores rather than a universal fixed ratio whenever possible.
- Low FVC is a prompt to investigate—not proof of restriction.
- Bronchodilator responsiveness is a physiological observation, not a disease label.
- Compare serial tests using the same reference equations, equipment standards and clinical conditions.
- Unexpected results should trigger a repeat test or full PFTs—not reflex diagnostic labeling.

Take-home messages

01

Spirometry is effort-dependent

Technique and quality determine whether the numbers are trustworthy.

02

The ratio identifies obstruction

FEV_1/FVC below LLN is the key spirometric criterion.

03

TLC confirms restriction

A low FVC alone cannot establish restrictive physiology.

04

Interpret the patient, not just the printout

Patterns must be integrated with symptoms, exposures and other tests.