Spirometry

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MD FRCPC
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Objectives

- This session will review:
  1) Common measures obtained during spirometry
  2) Indications and C/I to spirometry
  3) An approach to spirometry interpretation
  4) Several examples of spirometry and their interpretations

Disclosures

- I have received honoraria/speaking fees for CME sessions funded by AstraZeneca, Valeo and GSK, none of which are related to today's content
- The university will provide an honoraria for this talk

Most Important

- Quality Control/Calibration
- Technical considerations
- Coaching

Spirometry

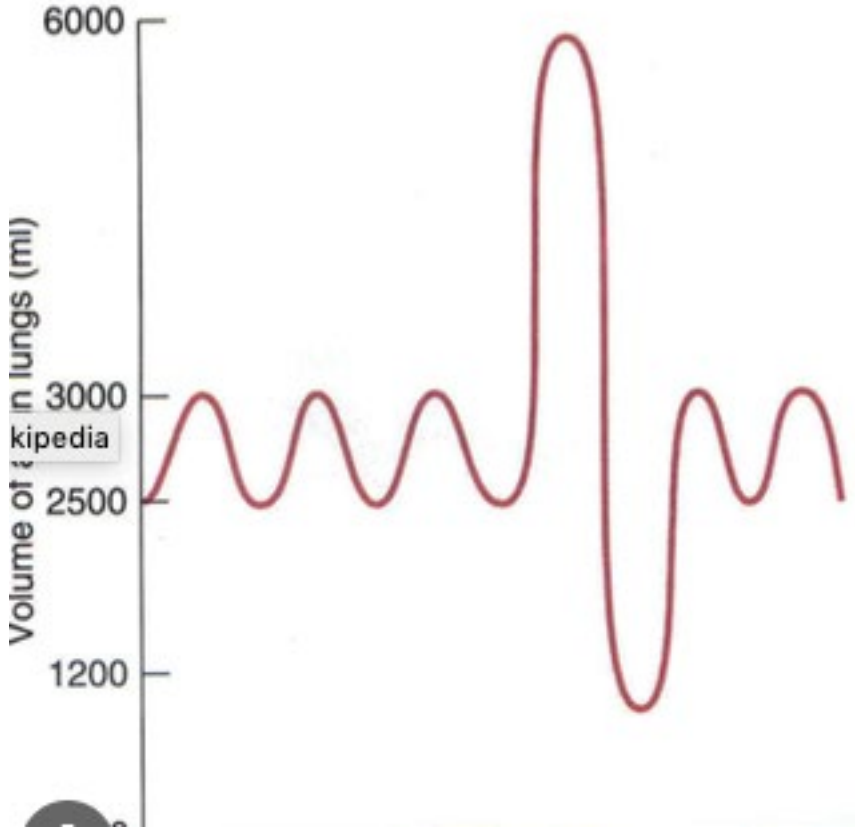
- Physiological test measuring maximally inspired/expired air volume(s)/flow(s)
- Entirely dependent on effort and test technique
- Measures volume or flow vs time
- Most relevant measures are the FEV1 and FVC
- Other measures reported incl PEF, PIF and mid expiratory flows

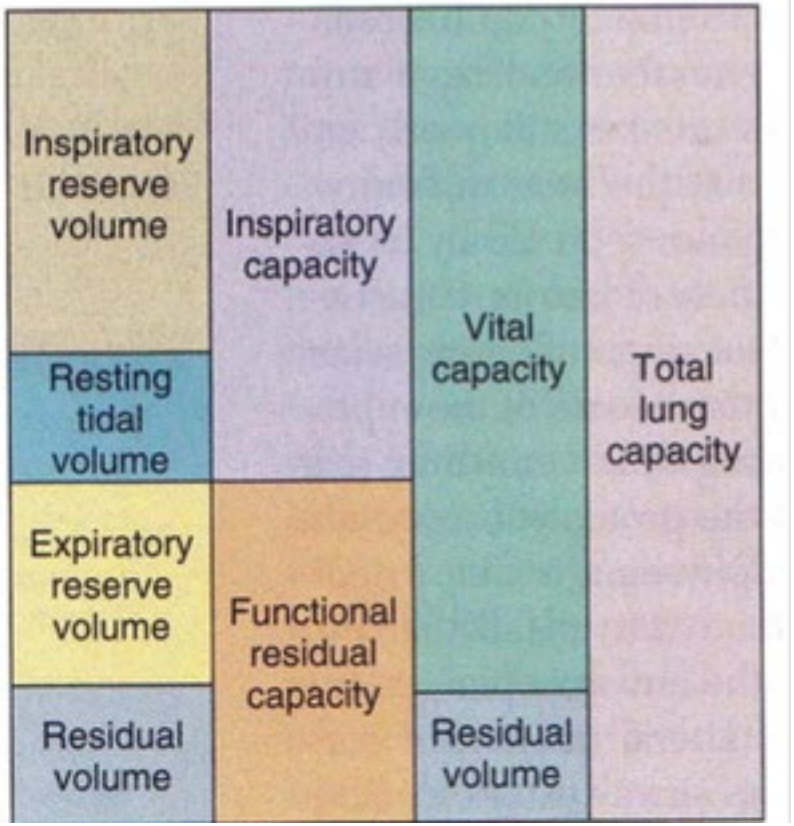
Definitions

- FVC: **maximal** volume of air exhaled with **maximally** forced effort from a **maximal** inspiration expressed in L
- FEV1: is the maximal volume of air exhaled in the first second of a forced expiration from a position of full inspiration, expressed in L.

Physiology

- Expiratory airflow measured with spirometry is determined by the driving pressure and size/viscoelastic properties of lungs/airways
- The driving pressure is dependent on effort, respiratory muscle function and elastic recoil of the respiratory system
- Resistance to airflow can be due to obstruction of a central airway or to intrapulmonary airflow obstruction


6000
3000
2500
1200
Volume of
n lungs (ml)
kipedia


Inspiratory reserve volume
Resting tidal volume
Expiratory reserve volume
Residual volume
Inspiratory capacity
Functional residual capacity
Vital capacity
Residual volume
Total lung capacity

Considerations Prior to Testing

Table 2.

Relative Contraindications for Spirometry

Due to increases in myocardial demand or changes in blood pressure
Acute myocardial infarction within 1 wk
Systemic hypotension or severe hypertension
Significant atrial/ventricular arrhythmia
Noncompensated heart failure
Uncontrolled pulmonary hypertension
Acute cor pulmonale
Clinically unstable pulmonary embolism
History of syncope related to forced expiration/cough
Due to increases in intracranial/intraocular pressure
Cerebral aneurysm
Brain surgery within 4 wk
Recent concussion with continuing symptoms
Eye surgery within 1 wk

Considerations Prior to Testing

Due to increases in sinus and middle ear pressures

- Sinus surgery or middle ear surgery or infection within 1 wk

Due to increases in intrathoracic and intraabdominal pressure

- Presence of pneumothorax
- Thoracic surgery within 4 wk
- Abdominal surgery within 4 wk
- Late-term pregnancy

Infection control issues

- Active or suspected transmissible respiratory or systemic infection, including tuberculosis
- Physical conditions predisposing to transmission of infections, such as hemoptysis, significant secretions, or oral lesions or oral bleeding

Considerations Prior to Testing

TABLE 2 Activities that should preferably be avoided prior to lung function testing

Smoking within at least 1 h of testing
Consuming alcohol within 4 h of testing
Performing vigorous exercise within 30 min of testing
Wearing clothing that substantially restricts full chest and abdominal expansion
Eating a large meal within 2 h of testing

Considerations Prior to Testing

TABLE 1 Indications for spirometry

Diagnostic

- To evaluate symptoms, signs or abnormal laboratory tests
- To measure the effect of disease on pulmonary function
- To screen individuals at risk of having pulmonary disease
- To assess pre-operative risk
- To assess prognosis
- To assess health status before beginning strenuous physical activity programmes

Monitoring

- To assess therapeutic intervention
- To describe the course of diseases that affect lung function
- To monitor people exposed to injurious agents
- To monitor for adverse reactions to drugs with known pulmonary toxicity

Disability/impairment evaluations

- To assess patients as part of a rehabilitation programme
- To assess risks as part of an insurance evaluation
- To assess individuals for legal reasons

Public health

- Epidemiological surveys
- Derivation of reference equations
- Clinical research

TABLE 4 Procedures for recording forced vital capacity

Check the spirometer calibration

Explain the test

Prepare the subject

- Ask about smoking, recent illness, medication use, *etc*.
- Measure weight and height without shoes

Wash hands

Instruct and demonstrate the test to the subject, to include

- Correct posture with head slightly elevated
- Inhale rapidly and completely
- Position of the mouthpiece (open circuit)
- Exhale with maximal force

Perform manoeuvre (closed circuit method)

- Have subject assume the correct posture
- Attach nose clip, place mouthpiece in mouth and close lips around the mouthpiece
- Inhale completely and rapidly with a pause of <1 s at TLC
- Exhale maximally until no more air can be expelled while maintaining an upright posture
- Repeat instructions as necessary, coaching vigorously
- Repeat for a minimum of three manoeuvres; no more than eight are usually required
- Check test repeatability and perform more manoeuvres as necessary

Perform manoeuvre (open circuit method)

- Have subject assume the correct posture
- Attach nose clip
- Inhale completely and rapidly with a pause of <1 s at TLC
- Place mouthpiece in mouth and close lips around the mouthpiece
- Exhale maximally until no more air can be expelled while maintaining an upright posture
- Repeat instructions as necessary, coaching vigorously
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Reversibility testing

- Withhold SABD/LABD if want to know if *any* reversibility present (4h and 24h, respectively)
- Continue SABD/LABD if want to know if *ongoing* reversibility present
- Dose:
  - Ventolin 100mcg puffs x 4 (30s apart) with spacer - retest 10-15min

Interpretation Steps

- Demographics
- Review historical information / RT Comments
- Look at the flow volume loop
- Assess for airflow obstruction
- Look at the FEV1 and FVC
- Review post BD spirometry if available

Demographics

- Patient name
- DOB
- Date and location of test
- Height/Weight/BMI
- Race

Demographics

Name	[redacted]	PHIN:	[redacted]	Date	2023-01-25
Tech:	Thibeault, Lisa	Height:	179.00	Age: 61	Room:
Doctor:	Orlikow, Evan	Weight:	93.00	Sex: Male	Race: Caucasian

Historical Information

The Winnipeg Clinic
425 St Mary Ave
Winnipeg, MB R3C 0N2
Pulmonary Function Laboratory

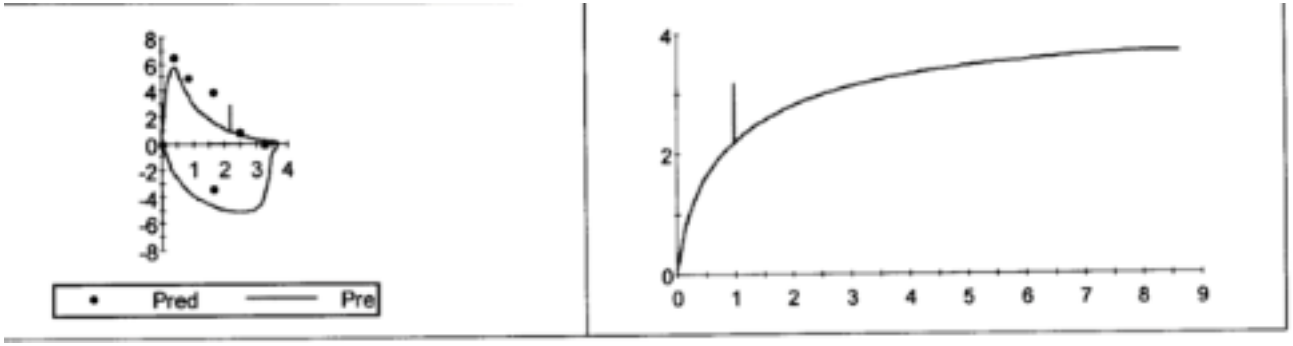
Name	[redacted]	PHIN:	[redacted]	Date	2023-07-17
Tech:	Yankech, Lisa	Height:	174.50	Age: 56	Room: Main
Doctor:	Orlikow, E	Weight:	98.00	Sex: Male	Race: NE Asian

Diagnosis:
Dyspnea: After severe exertion **Cough:** Non-Productive **Wheeze:** Frequent
Tobacco Cigarette **Yrs Smk:** 12.0 **Pks/Day:** 1.0 **Yrs Quit:** 0.5
Medications: Flovent; Ventolin
Post Test Comments: Good patient effort & cooperation.

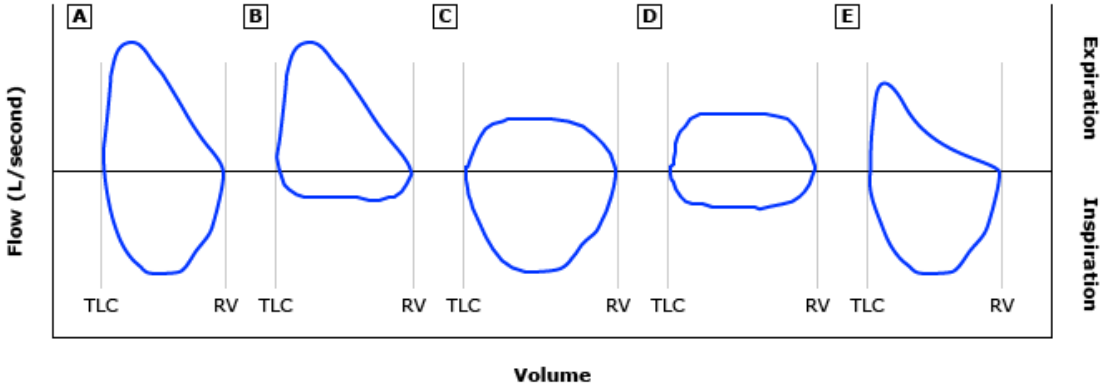
	Pre-Bronch			Post-Bronch		
	Actual	Pred	%Pred	Actual	%Pred	%Chng
---- SPIROMETRY ----						
FVC (L)	4.60	4.40	104	5.19	118	+12
FEV1 (L)	2.26	3.46	65	2.93	84	+29
FEV1/FVC (%)	49	79	62	57	71	+15
FEF 25% (L/sec)	2.38	7.78	30	4.22	54	+76
FEF 75% (L/sec)	0.29	1.12	25	0.82	72	+181
FEF 25-75% (L/sec)	0.75	3.03	24	1.77	58	+134
FEF Max (L/sec)	5.88			6.80		+15
FIVC (L)	4.54			5.18		+14
FIF Max (L/sec)	7.16			5.31		-25
FIF 25% (L/sec)	5.83			4.43		-24

FVL

- Does the technique look good? Free from artifact? Expected shape?
- Does it look normal, restricted, or obstructive?
- If it looks abnormal, what is the cause?
- Be sure to also look at the inspiratory loop



Flow-volume loops in upper airway obstruction



The configuration of the flow-volume loop can help distinguish the site of airway narrowing. The airways are divided into intrathoracic and extrathoracic components by the thoracic inlet.

(A) Normal flow-volume loop: the expiratory portion of the flow-volume curve is characterized by a rapid rise to the peak flow rate, followed by a nearly linear fall in flow. The inspiratory curve is a relatively symmetrical, saddle-shaped curve.

(B) Dynamic (or variable, nonfixed) extrathoracic obstruction: flow limitation and flattening are noted on the inspiratory limb of the loop.

(C) Dynamic (or variable, nonfixed) intrathoracic obstruction: flow limitation and flattening are noted on the expiratory limb of the loop.

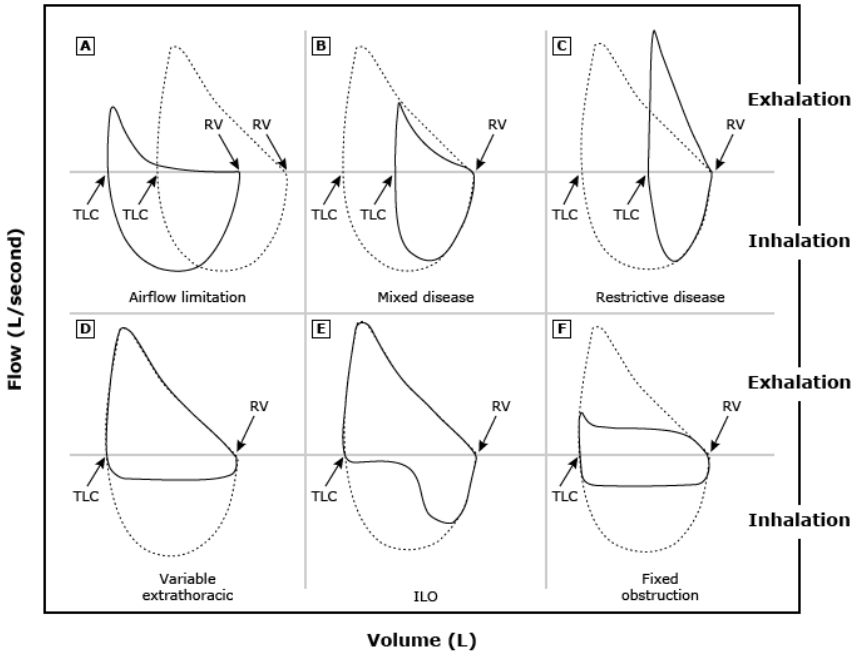
(D) Fixed upper airway obstruction (can be intrathoracic or extrathoracic): flow limitation and flattening are noted in both the inspiratory and expiratory limbs of the flow-volume loop.

(E) Peripheral or lower airways obstruction: expiratory limb demonstrates concave upward, also called "scooped-out" or "coved" pattern.

TLC: total lung capacity; RV: residual volume.

Adapted from: Stoller JK. Spirometry: a key diagnostic test in pulmonary medicine. Cleve Clin J Med 1992; 59:75.

Common patterns on flow-volume loops



The flow-volume loops are plotted against absolute lung volume to show the influence of changes in lung volume. For both loops in each panel, the leftward intersection with the horizontal axis is at total lung capacity (TLC, maximal inhalation) and the rightward intersection is at residual volume (RV, maximal exhalation).

(A) Patient with airflow limitation (solid lines) compared to predicted (dashed lines).

(B) Patient with mixed disease with reduced airflow and reduced lung volumes. It is important to note that if one only measures airflow, this mixed picture would have been missed.

(C) The flow-volume loop observed in a patient with restrictive disease where the increased recoil causes increased airflow.

(D) Consistent truncation of the inspiratory phase of the loop, characteristic of a variable extrathoracic obstruction, eg, tracheal collapse as might be due to intubation trauma.

(E) Another extrathoracic process of a more transient nature characteristic of vocal cord dysfunction.

(F) Consistent truncation of both inspiration and expiration, characteristic of a fixed obstruction, eg, tracheal stenosis.

TLC: total lung capacity; RV: residual volume; ILO: inducible laryngeal obstruction.

Airflow obstruction

- What is the ratio of the absolute FEV1 to absolute FVC
  -Not the FEV1% : FVC%
- < .70 = airflow obstruction is present
  -This may be due to aging and not ‘disease’
- Use of the LLN is also prevalent
  -A ratio of 80-85+ is expected for children
  -A ratio of 60-65 may be expected for 80+ yo
  -LLN is not the same as ‘predicted’

Airflow obstruction

- Need to keep in mind the clinical context, FVC, technique, other factors that can affect FVC, day to day variability
- Patients can have a preserved ratio (ie. > 70 or LLN) with scooping of the FVL
  -sometimes we call this ‘early small airways disease’ or ‘small airways obstruction’
  -careful not to overcall this

FEV1 and FVC

- If there's airflow obstruction, we want to know how low the FEV1 is and also what the FVC is
- If the FVC is also low, this can be due to gas trapping (high RV), or due to concomitant lung volume restriction (low TLC). This can only be determined with full PFTs

FEV1 and FVC

- If airflow obstruction is absent, we still want to know what the FEV1 and FVC are.
- If they're both low this is *suggestive* of lung volume restriction
  -This still needs to be confirmed with full PFT
  -People can have a low FEV1 and FVC and a normal TLC and therefore do not have lung volume restriction. This is called PRISM or the non specific pattern

Post BD Spirometry

- Look to see if the FEV1 or the FVC have increased by at least 200 cc and 12% (relative)
- These cutoffs are in flux, may use 10% of the absolute value as well
- NB if FVC increases significantly but FEV1 doesn't it may be due to test technical reasons (longer exhalation time in the post BD spiro)
- NB a positive BD response (12% and 200 cc) is non specific. As these numbers get bigger it becomes more specific for asthma

Regarding our formal interpretations

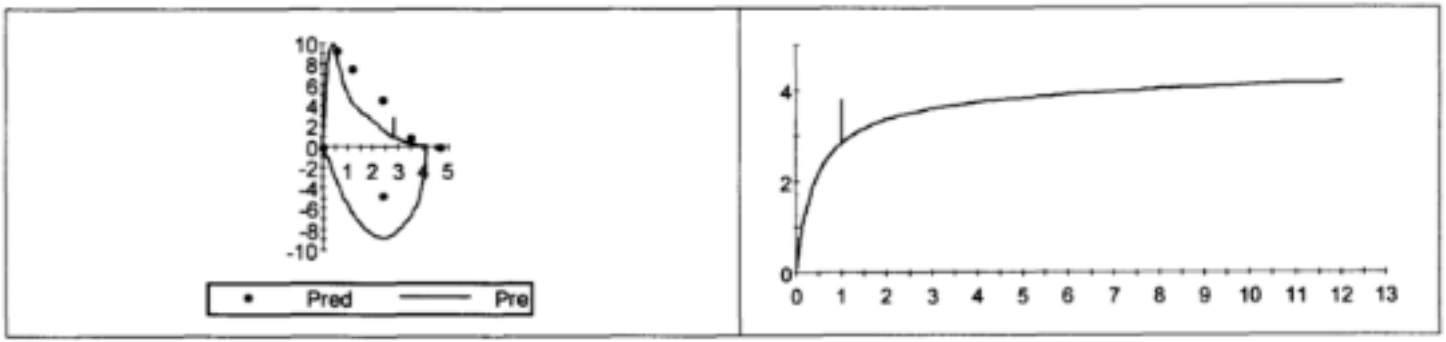
- Guideline (not gestalt) based
- We (often) lack the clinical context
- Like anyone else interpreting tests, sometimes we need to be hedgy
- It's easier interpreting tests when you know the patient and often there are subtleties to the results that you can glean only when you know the clinical context

The Winnipeg Clinic
425 St Mary Ave
Winnipeg, MB R3C 0N2
Pulmonary Function Laboratory

Name	[redacted]	PHIN:	[redacted]	Date	2023-01-25		
Tech:	Thibeault, Lisa	Height:	179.00	Age:	61	Room:	
Doctor:	Orlikow, Evan	Weight:	93.00	Sex:	Male	Race:	Caucasian

Post Test Comments: good effort

	Pre-Bronch			Post-Bronch		
	Actual	Pred	%Pred	Actual	%Pred	%Chng
---- SPIROMETRY ----						
FVC (L)	4.17	4.68	89			
FEV1 (L)	2.83	3.60	78			
FEV1/FVC (%)	68	77	87			
FEF 25% (L/sec)	4.83	7.59	63			
FEF 75% (L/sec)	0.52	0.90	57			
FEF 25-75% (L/sec)	1.58	2.97	53			
FEF Max (L/sec)	9.96	9.26	107			
FIVC (L)	4.13					
FIF Max (L/sec)	8.87					



The Winnipeg Clinic
425 St Mary Ave
Winnipeg, MB R3C 0N2
Pulmonary Function Laboratory

Name	[redacted]	PHIN:	[redacted]	Date	2022-12-15		
Tech:	Yankech, Lisa	Height:	159.00	Age:	39	Room:	
Doctor:	Orlikow, Evan	Weight:	70.00	Sex:	Female	Race:	Asian

Post Test Comments: Good patient effort & cooperation. Pt used Symbicort today.

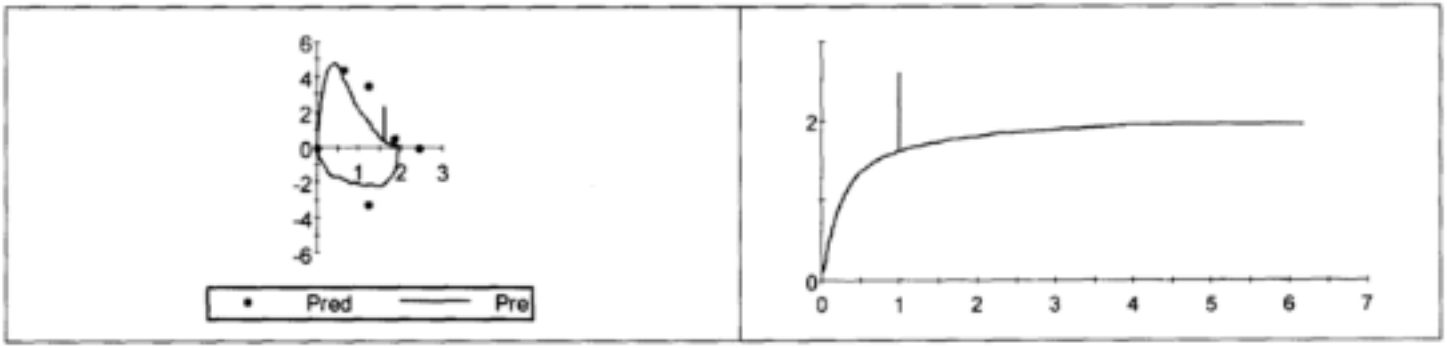
	Pre-Bronch			Post-Bronch		
	Actual	Pred	%Pred	Actual	%Pred	%Chng
---- SPIROMETRY ----						
FVC (L)	3.71	3.24	114			
FEV1 (L)	3.16	2.70	116			
FEV1/FVC (%)	85	84	101			
FEF 25% (L/sec)	8.50	5.34	159			
FEF 75% (L/sec)	1.54	1.17	132			
FEF 25-75% (L/sec)	3.35	2.96	113			
FEF Max (L/sec)	9.05					
FIVC (L)	3.67					
FIF Max (L/sec)	5.56					

The Winnipeg Clinic
425 St Mary Ave
Winnipeg, MB R3C 0N2
Pulmonary Function Laboratory

Name	[redacted]	PHIN:	[redacted]	Date	2023-09-05		
Tech:	Cote, Chelsea	Height:	153.00	Age:	64	Room:	
Doctor:	Orlikow, Evan	Weight:	65.00	Sex:	Female	Race:	Asian

Post Test Comments: Good patient effort & cooperation.

	Pre-Bronch			Post-Bronch		
	Actual	Pred	%Pred	Actual	%Pred	%Chng
---- SPIROMETRY ----						
FVC (L)	1.96	2.44	80			
FEV1 (L)	1.62	1.95	83			
FEV1/FVC (%)	83	80	103			
FEF 25% (L/sec)	4.64	4.49	103			
FEF 75% (L/sec)	0.64	0.49	131			
FEF 25-75% (L/sec)	1.77	1.83	96			
FEF Max (L/sec)	4.75					
FIVC (L)	1.98					
FIF Max (L/sec)	2.19					

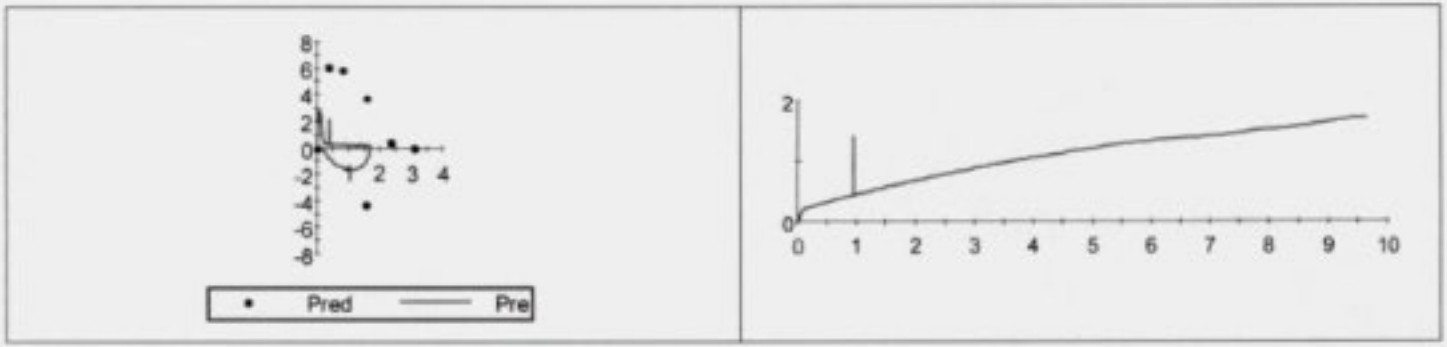


The Winnipeg Clinic
425 St Mary Ave
Winnipeg, MB R3C 0N2
Pulmonary Function Laboratory

Name	[redacted]	PHIN:	[redacted]	Date	2023-09-07		
Tech:	Mouritsen, Carly	Height:	160.00	Age:	77	Room:	
Doctor:	Orlikow, Evan	Weight:	70.00	Sex:	Male	Race:	Caucasian

Post Test Comments: Good patient effort & cooperation.

	Pre-Bronch			Post-Bronch		
	Actual	Pred	%Pred	Actual	%Pred	%Chng
---- SPIROMETRY ----						
FVC (L)	1.70	3.10	55			
FEV1 (L)	0.44	2.35	18			
FEV1/FVC (%)	26	76	34			
FEF 25% (L/sec)	0.24	5.98	3			
FEF 75% (L/sec)	0.17	0.44	39			
FEF 25-75% (L/sec)	0.19	1.80	10			
FEF Max (L/sec)	2.71	6.10	44			
FIVC (L)	1.53					
FIF Max (L/sec)	1.73					



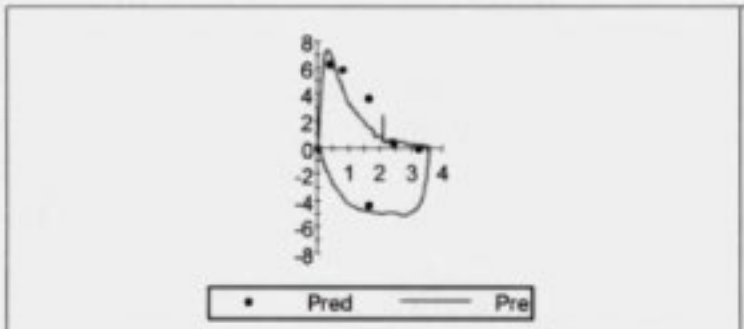
The Winnipeg Clinic
425 St Mary Ave
Winnipeg, MB R3C 0N2
Pulmonary Function Laboratory

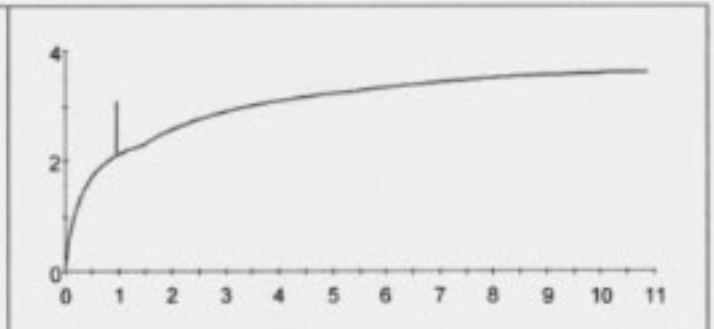
Name	[redacted]	PHIN:	[redacted]	Date	2023-09-07
Tech:	Al-Azazi, Maryam	Height:	162.00	Age:	76
Doctor:	Orlikow, Evan	Weight:	67.00	Sex:	Male

Room:
Race: Caucasian

Post Test Comments: Best effort

	Pre-Bronch			Post-Bronch		
	Actual	Pred	%Pred	Actual	%Pred	%Chng
---- SPIROMETRY ----						
FVC (L)	3.60	3.22	111			
FEV1 (L)	2.12	2.45	86			
FEV1/FVC (%)	59	76	77			
FEF 25% (L/sec)	3.94	5.98	65			
FEF 75% (L/sec)	0.39	0.46	84			
FEF 25-75% (L/sec)	0.82	1.87	44			
FEF Max (L/sec)	7.32	6.38	114			
FIVC (L)	3.48					
FIF Max (L/sec)	5.13					





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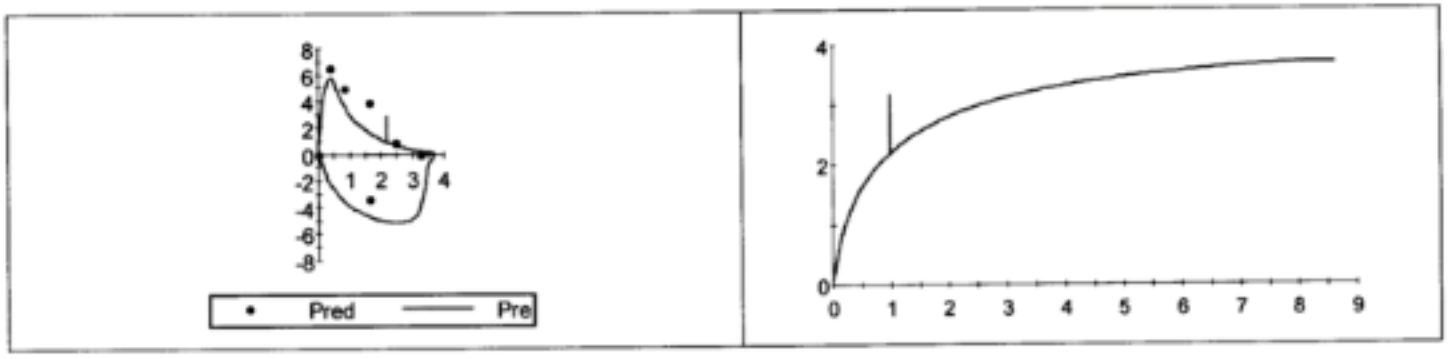
Pulmonary Function Laboratory

Name	[redacted]	PHIN:	[redacted]	Date	2023-09-07		
Tech:	Mouritsen, Carly	Height:	159.00	Age:	51	Room:	
Doctor:	Orlikow, Evan	Weight:	49.00	Sex:	Female	Race:	Caucasian

Post Test Comments: Good patient effort & cooperation.

	Pre-Bronch			Post-Bronch		
	Actual	Pred	%Pred	Actual	%Pred	%Chng
---- SPIROMETRY ----						
FVC (L)	3.69	3.26	113			
FEV1 (L)	2.20	2.61	83			
FEV1/FVC (%)	59	81	73			
FEF 25% (L/sec)	3.21	5.05	63			
FEF 75% (L/sec)	0.47	0.84	55			
FEF 25-75% (L/sec)	1.06	2.60	40			
FEF Max (L/sec)	5.74	6.49	88			
FIVC (L)	3.69					
FIF Max (L/sec)	5.15					



Patient Details

ID: [redacted]
First Name: [redacted]
Last Name: [redacted]
Smoker: No

Birth Date [redacted]
Age: 42
Gender: Female
Ethnicity: Caucasian

Height: 174 cm
Weight: 157 kg
BMI 51.86
Hb: --- mmol/L
O2% Sat.: --- %

Session Details

Start Time: 20 Jul, 2023 9:11 AM
Technician:
Maryam Al-Azazi RRT BRT
Physician:
Dr. E. Orlikow

Multiple attempts for FVC, best effort reported.
Audible stridor t/o testing plus at rest.

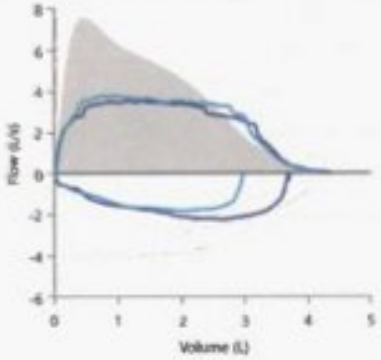
Medical Condition ---
Reimbursement Codes: ---
LLN: 70%

Prediction

Adults System Default

FVC

		Pred.	Pre Best	Pre Gr.	Pre % Pred.	Post Best	Post Gr.	Post % Pred.	% Change
FVC	L	4.25	4.35	E	102%	4.17	B	98%	▼ -4%
FEV1	L	3.43	3.21	C	94%	3.26	B	95%	▲ 2%
FEV1/FVC	%	81.31	73.29		90%	78.31		96%	▲ 7%
FEF 25	L/sec	6.15	3.44		56%	3.72		60%	▲ 8%
FEF 75	L/sec	1.33	1.61		121%	1.81		136%	▲ 12%
FEF 25-75	L/sec	3.40	2.94		86%	3.26		96%	▲ 11%
PEF	L/sec	7.20	3.52		49%	3.76		52%	▲ 7%
Lung Age	Years	42.01	67.82		161%	65.12		155%	▼ -4%



The Winnipeg Clinic
425 St Mary Ave
Winnipeg, MB R3C 0N2
Pulmonary Function Laboratory

3.11522J

Name	[redacted]	PHIN:	[redacted]	Date	2023-07-31		
Tech:	Yankech, Lisa	Height:	176.50	Age:	62	Room:	
Doctor:	Orlikow, Evan	Weight:	112.00	Sex:	Male	Race:	Caucasian

BMI 35.9

Post Test Comments: best effort

	Pre-Bronch			Post-Bronch		
	Actual	Pred	%Pred	Actual	%Pred	%Chng
---- SPIROMETRY ----						
FVC (L)	2.78	4.48	61			
FEV1 (L)	2.36	3.46	68			
FEV1/FVC (%)	85	77	110			
FEF 25% (L/sec)	4.89	8.00	61			
FEF 75% (L/sec)	1.24	0.85	146			
FEF 25-75% (L/sec)	2.44	2.84	86			
FEF Max (L/sec)	5.20	8.96	58			
FIVC (L)	2.80					
FIF Max (L/sec)	2.66					

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Pulmonary Function Laboratory

Name	[redacted]	PHIN:	[redacted]	Date	2023-07-17
Tech:	Yankech, Lisa	Height:	174.50	Age: 56	Room: Main
Doctor:	Orlikow, E	Weight:	98.00	Sex: Male	Race: NE Asian

Diagnosis:
Dyspnea: After severe exertion **Cough:** Non-Productive **Wheeze:** Frequent
Tobacco Cigarette **Yrs Smk:** 12.0 **Pks/Day:** 1.0 **Yrs Quit:** 0.5
Medications: Flovent; Ventolin
Post Test Comments: Good patient effort & cooperation.

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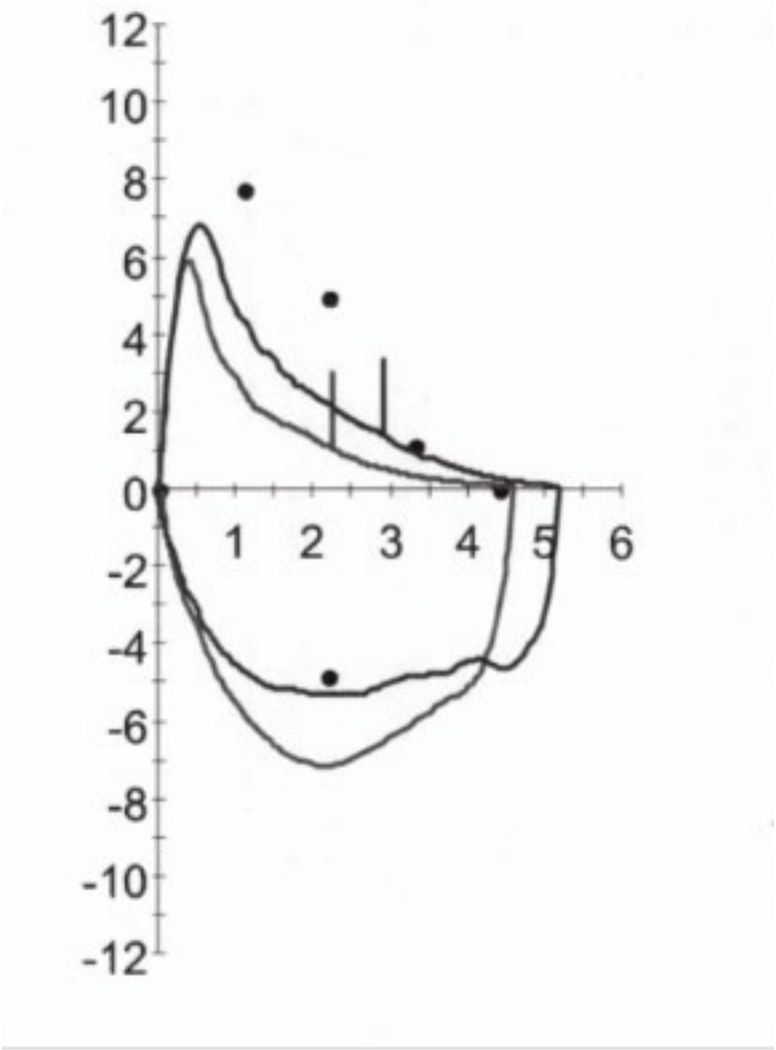
FEV1 (L)	2.26	3.46	65	2.93	84	+29
FEV1/FVC (%)	49	79	62	57	71	+15
FEF 25% (L/sec)	2.38	7.78	30	4.22	54	+76
FEF 75% (L/sec)	0.29	1.12	25	0.82	72	+181
FEF 25-75% (L/sec)	0.75	3.03	24	1.77	58	+134
FEF Max (L/sec)	5.88			6.80		+15
FIVC (L)	4.54			5.18		+14
FIF Max (L/sec)	7.16			5.31		-25
FIF 25% (L/sec)	5.83			4.43		-24

Example

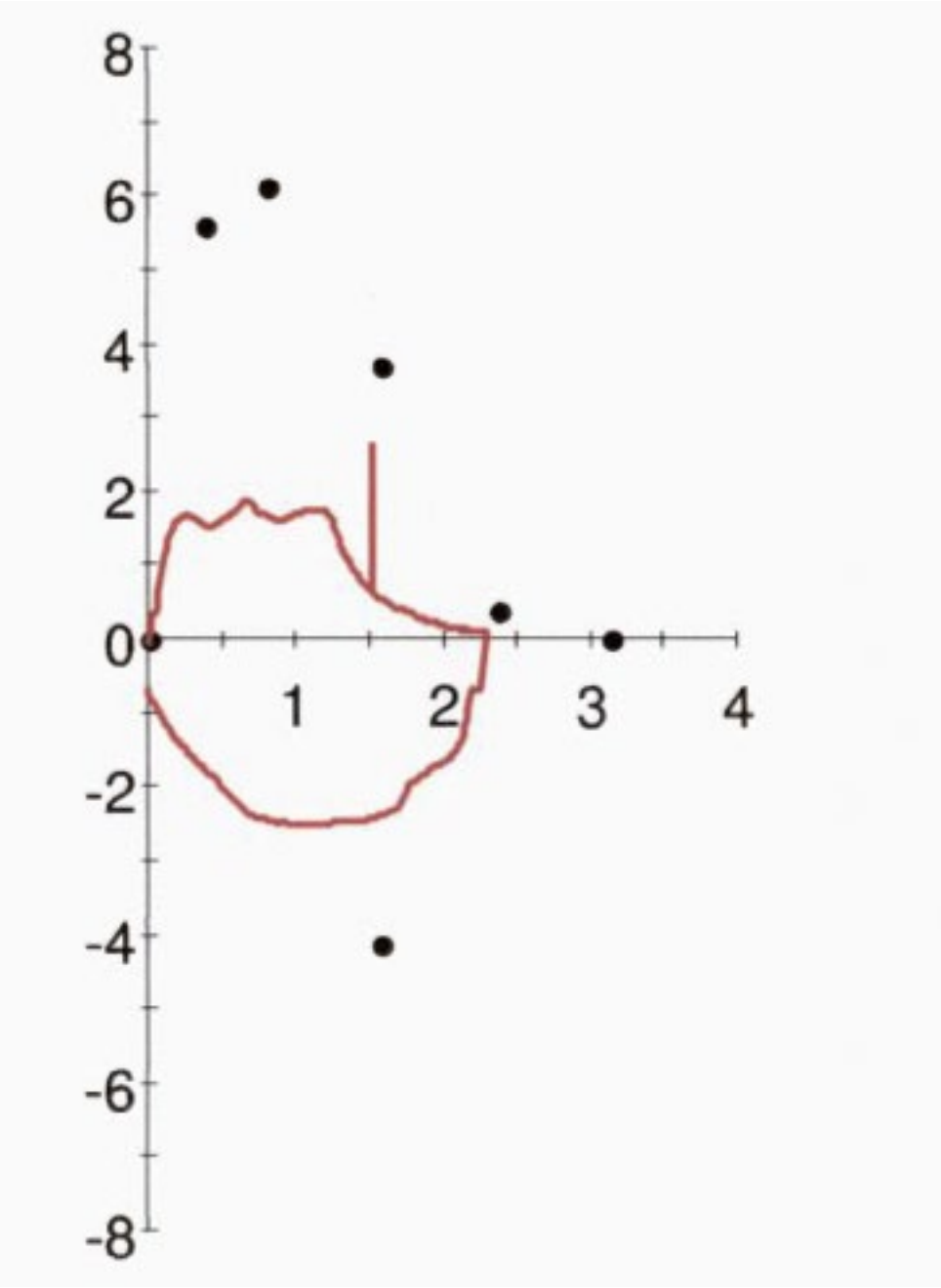


The Winnipeg Clinic
425 St Mary Ave
Winnipeg, MB R3C 0N2
Pulmonary Function Laboratory

Name:	[redacted]	PHIN:	[redacted]	Date	2022-05-10		
Tech:	Mouritsen, Carly	Height:	165.00	Age:	84	Room:	Main Lab
Doctor:	Orlikow, E	Weight:	79.40	Sex:	Male	Race:	Caucasian

Diagnosis:
Dyspnea: **Cough:** **Wheeze:**
Tobacco **Yrs Smk:** **Pks/Day:** **Yrs Quit:**
Medications: Symbicort
Post Test Comments: Good patient effort & cooperation. All expiratory loops were repeatable with good effort. Pt was unable to reach 90% of IC during DLCO maneuver d/t difficulty drawing in rapid deep breath, all attempts had repeatable results.

	Pre-Bronch			Post-Bronch		
	Actual	Pred	%Pred	Actual	%Pred	%Chng
---- SPIROMETRY ----						
FVC (L)	2.30	3.14	73			
FEV1 (L)	1.53	2.34	65			
FEV1/FVC (%)	66	75	88			
FEF 25% (L/sec)	1.68	6.16	27			
FEF 75% (L/sec)	0.39	0.39	101			
FEF 25-75% (L/sec)	1.02	1.67	61			
FEF Max (L/sec)	1.86	5.62	33			
FIVC (L)	2.37					
FIF Max (L/sec)	2.53					


8
6
4
2
0
-2
-4
-6
-8
1
2
3
4

Pulmonary Function Laboratory

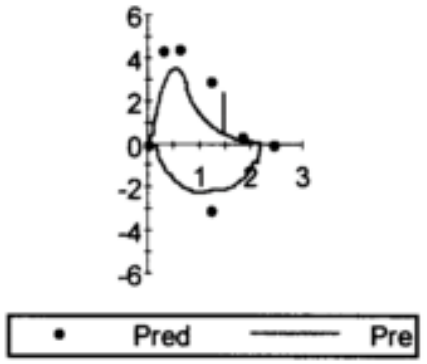
Name	[redacted]	PHIN:	[redacted]	Date	2022-10-20
Tech:	Cote, Chelsea	Height:	163.00	Age:	85
Doctor:	Orlikow, Evan	Weight:	78.60	Sex:	Female

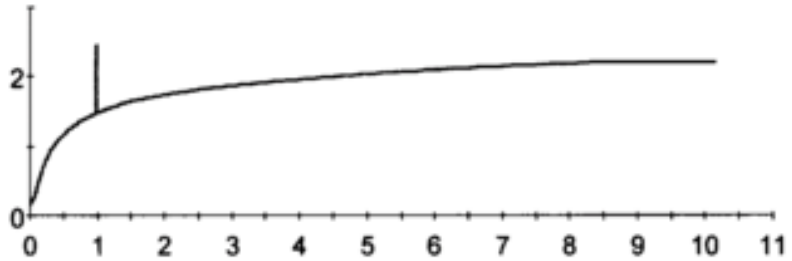
Room:

Race: Caucasian

Post Test Comments: Good patient effort & cooperation.

	Pre-Bronch			Post-Bronch		
	Actual	Pred	%Pred	Actual	%Pred	%Chng
---- SPIROMETRY ----						
FVC (L)	2.20	2.42	90			
FEV1 (L)	1.48	1.82	81			
FEV1/FVC (%)	67	76	87			
FEF 25% (L/sec)	3.50	4.40	79			
FEF 75% (L/sec)	0.23	0.30	75			
FEF 25-75% (L/sec)	0.78	1.43	54			
FEF Max (L/sec)	3.50	4.32	81			
FIVC (L)	2.02					
FIF Max (L/sec)	2.27					





References

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- R. Pellegrino, et al. Interpretative strategies for lung function tests. ERJ 2005.
- ERS/ATS technical standard on interpretive strategies for routine lung function tests. ERJ 2022.