Pulmonary Function Test Interpretation and Applications in Asthma Diagnosis and Management

Pediatric Postgraduate Conference 2019

Adaobi C. Kanu M.D.
Associate Professor of Pediatrics
Department of Pulmonology

Lecture Goals

- **Practitioners understand objectives and limitations of pulmonary function testing**
- **Practitioners understand spirometry methodology**
- **Practitioners recognize spirometry abnormalities**
- **Practitioners apply spirometry in asthma diagnosis and management**

Purpose of Spirometry

- Define lung disease **(obstructive vs. restrictive)**
- Define severity of lung disease
- Monitor disease progression and response to therapy
- Preoperative evaluation
- Aid in research study **(epidemiology; therapy)**

Pulmonary Function Testing: Limitations

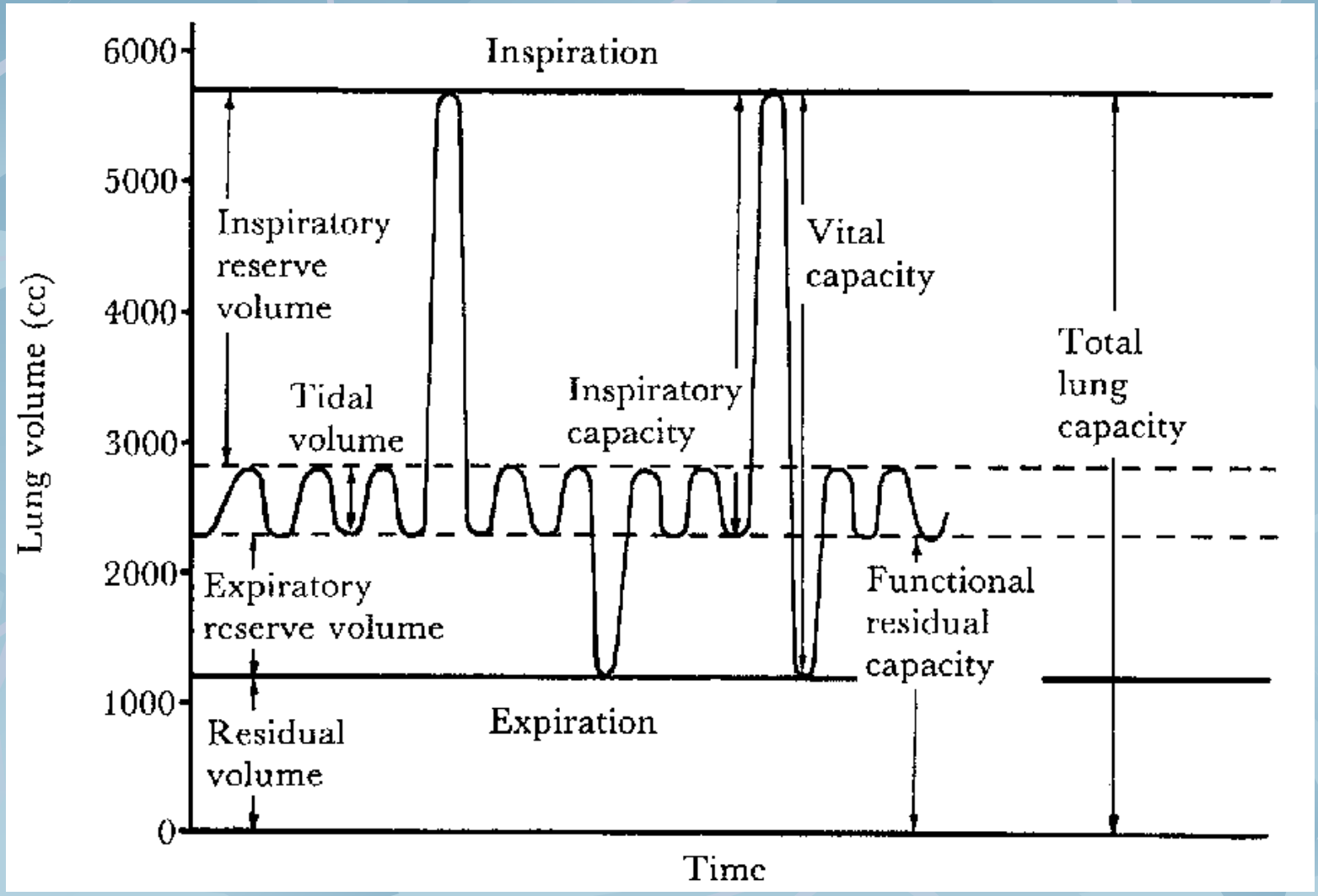
- Age: At least 5 years of age ideal due to effort but can be done as young as 3 years of age
- Subject ability and effort affects spirometry volumes
- Knowledge of operator

- Limited chest wall and abdominal expansion
  - Obese patients
  - Tight clothes
  - Heavy meal 2 hours prior to testing

- Noting ambient temperature and barometric pressure prior to machine calibration which can affect gas volumes

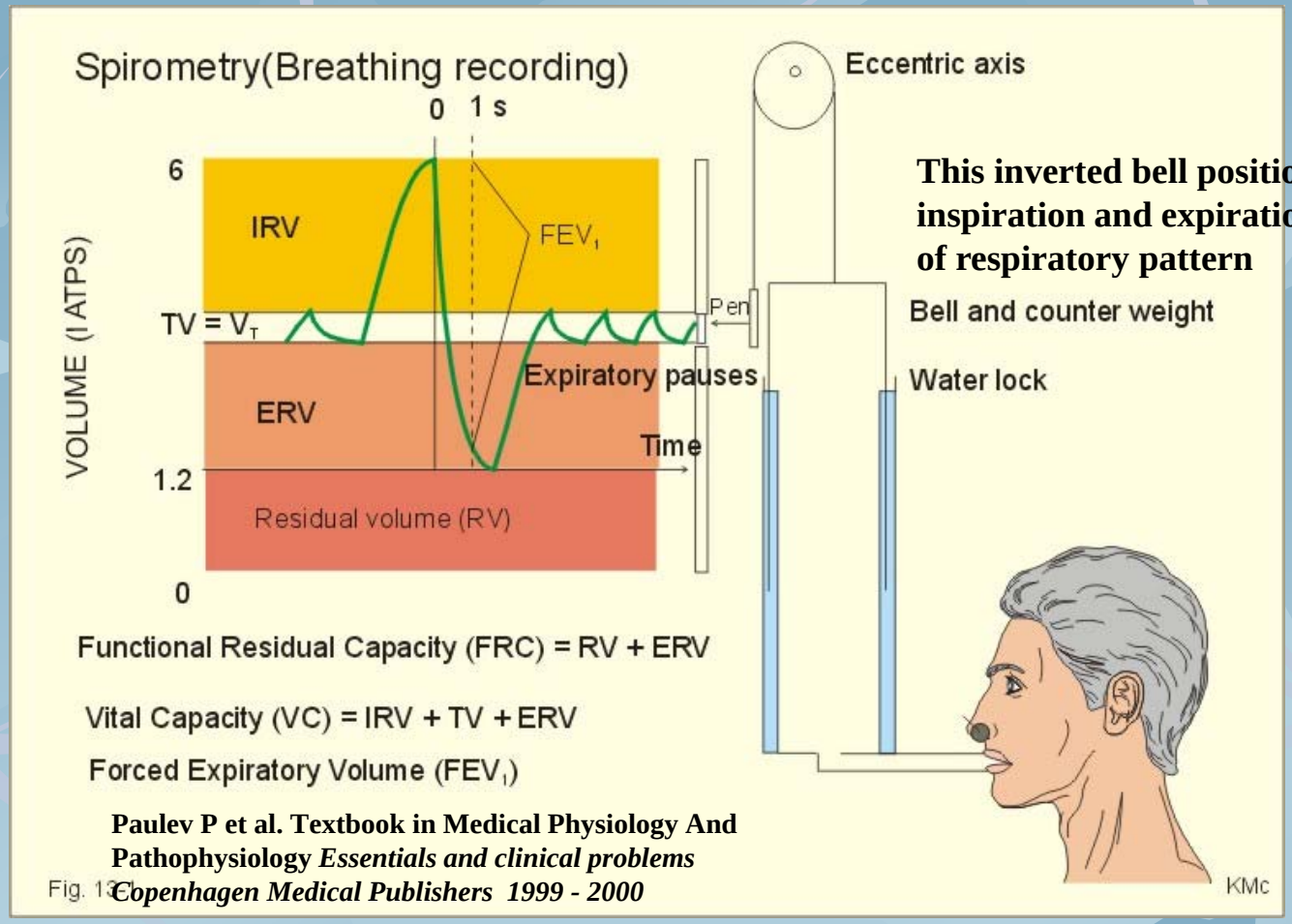
- Reference normal values
  - Should reflect patient population
  - Limited in those less than 3 years of age or 90 cm

Subdivisions of Lung Volume



Neligan, P. Introduction to Mechanical Ventilation - www.4um.com/images/lungvol.gif

Spirometry



This inverted bell position changed with inspiration and expiration causing a tracing of respiratory pattern

Consists of inverted canister or "bell" floating in a water filled space

The space inside the inner drum (closed to atmospheric pressure) is connected to a tubing extending to the mouthpiece.

During inspiration, the bell floats lower and raises on expiration.

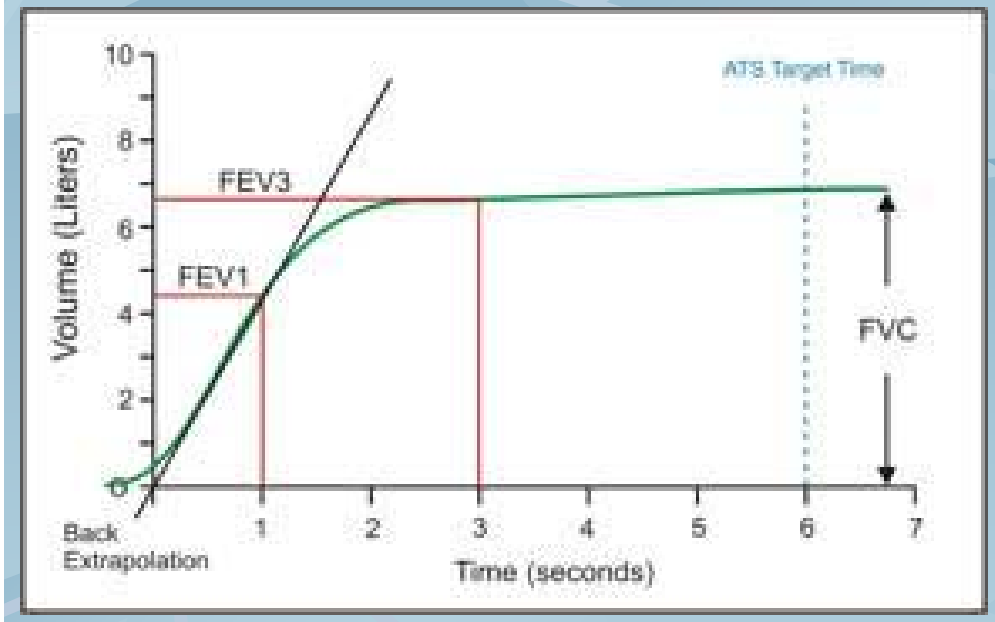
The bell is attached to a pulley and pen which traces the breathing pattern

Spirometry cannot measure residual volume, functional residual volume or total lung capacity

Levitsky MG. Pulmonary Physiology 7th ed. Pub. McGraw-Hill 2003

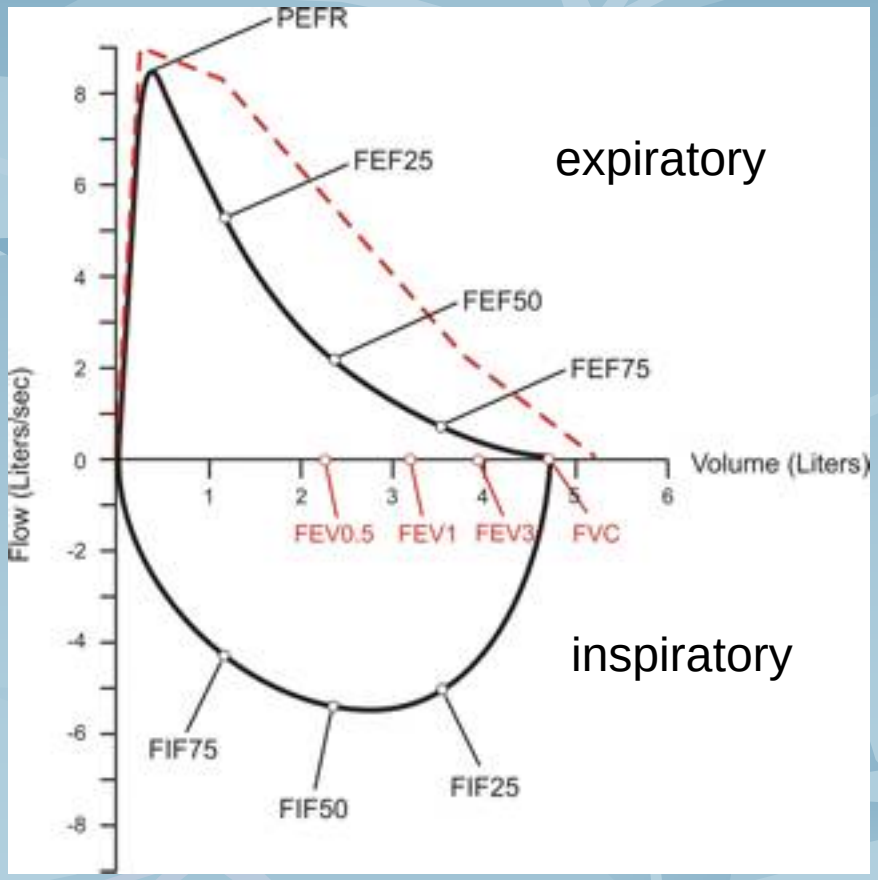
Spirometry Maneuvers

Expiratory Volume Time Loop

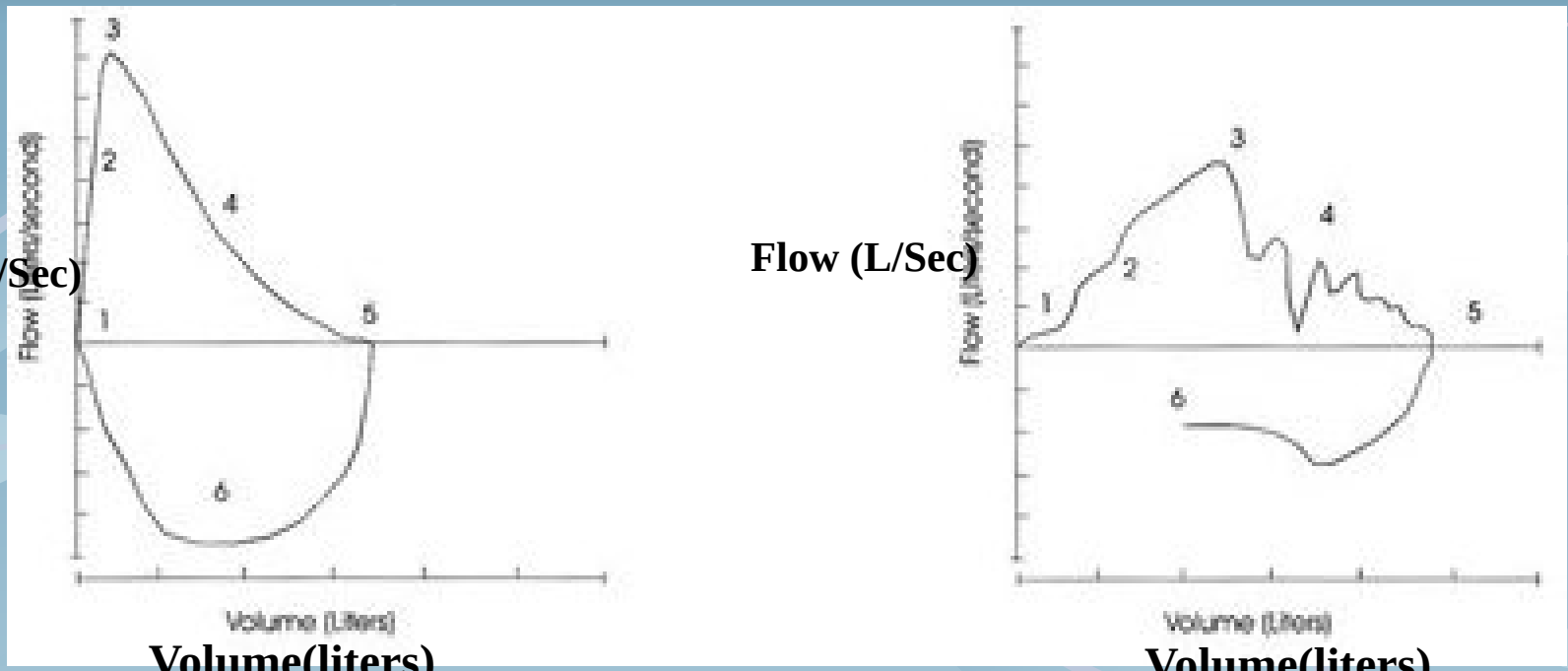


Morgan Scientific - www.morgansci.com/.../clip_image006_0000a.jpg

Flow Volume Loop



Morgan Scientific - www.morgansci.com/.../clip_image006_0000a.jpg



Good Spirometry Effort

1. Instantaneous start of exhalation
2. Rapid rise in flow to peak flow
3. Shap peak occuring early in exhalation
4. Smooth continuous fall in flow without interruption
5. Gradual fall in low flow to RV
6. Smooth continuous inhalation to TLC
7. Reproducible shape

Poor or Bad Spirometry Effort

1. Slow start
2. Slow rise in flow
3. Broad, late peak
4. Erratic Flow (cough)
5. Abrupt return to 0 flow
6. Incomplete inhalation
7. Non-reproducible

Spirometry Values

- Predicted normal values based on age, height, gender and race of healthy subjects
- Acceptable ATS-ERS criteria

  Adult: 3 efforts & variability of 5%; exhalation: 6 seconds

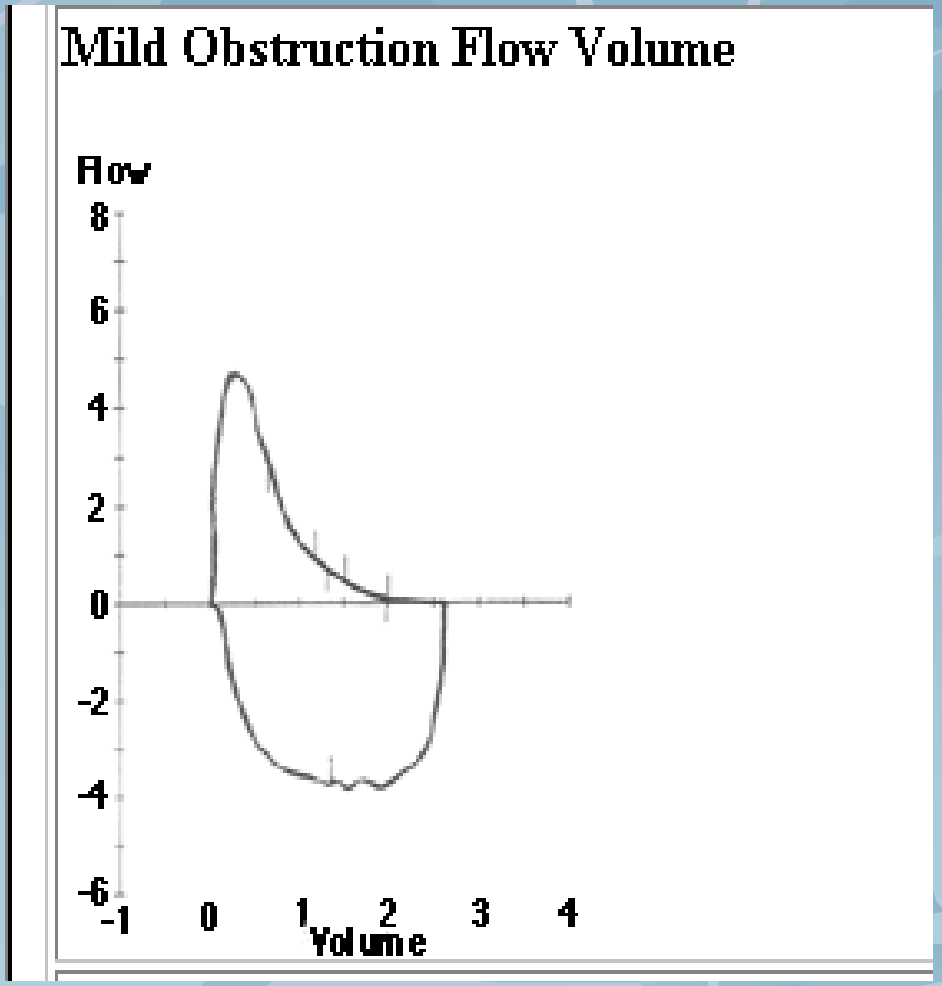
  Children: 2 efforts & variability within 10% ; exhalation can be as short as 3 to 5 seconds due to smaller lung volume
- FVC Forced Vital Capacity (liters)
- SVC Slow Vital Capacity (liters)
- FEV_1 Forced Expiratory Volume 1 sec (liters)
- $FEF_{25\%-75\%}$ Forced exp flow at 25% to 75% VC (liters/sec)
- FVC, SVC, FEV_1 - Effort dependant
- $FEF_{25\%-75\%}$ - Effort independent due to airway closure at lower lung volumes during forced exhalation

Normal Values For Pediatrics

- Forced vital capacity (FVC) ≥ 80% predicted
- Forced expiratory volume in 1 second (FEV1) ≥ 80% predicted
- FEV1/FVC 80% to 85% (range is age dependent and lower in those 35 years and older)
- Peak expiratory flow rate (PEFR) > 78 to 80% predicted
- Forced expiratory flows at 25 to 25% of VC ($FEF_{25\%-75\%}$) > 60 to 65% predicted
- Total Lung Capacity (TLC) 80 to 100% predicted
  - cannot be measured with spirometry; can confirm restrictive disease
- Residual Volume (RV) 60 to 160% predicted
  - cannot be measured with spirometry
- RV/TLC ratio 30 to 35%
  - cannot be measured with spirometry; index of gas or air trapping

Obstructive Lung Disease

- FVC normal or decreased (high RV)
- FEV_1 decreased
- FEV_1/FVC ratio decreased
- Decreased $FEF_{25\%-75\%}$ relative to FEV_1 resulting in concave curve shape
- Internal airway obstruction (asthma, cystic fibrosis, bronchiolitis, chronic aspiration, intrathoracic tracheal and bronchomalacia, intrathoracic airway foreign body, bronchiectasis, bronchiolitis obliterans)
- External airway obstruction (mediastinal adenopathy, vascular anomaly – vascular ring or compression of airway, cardiac chamber enlargement)



Concave shaped expiratory flow loop

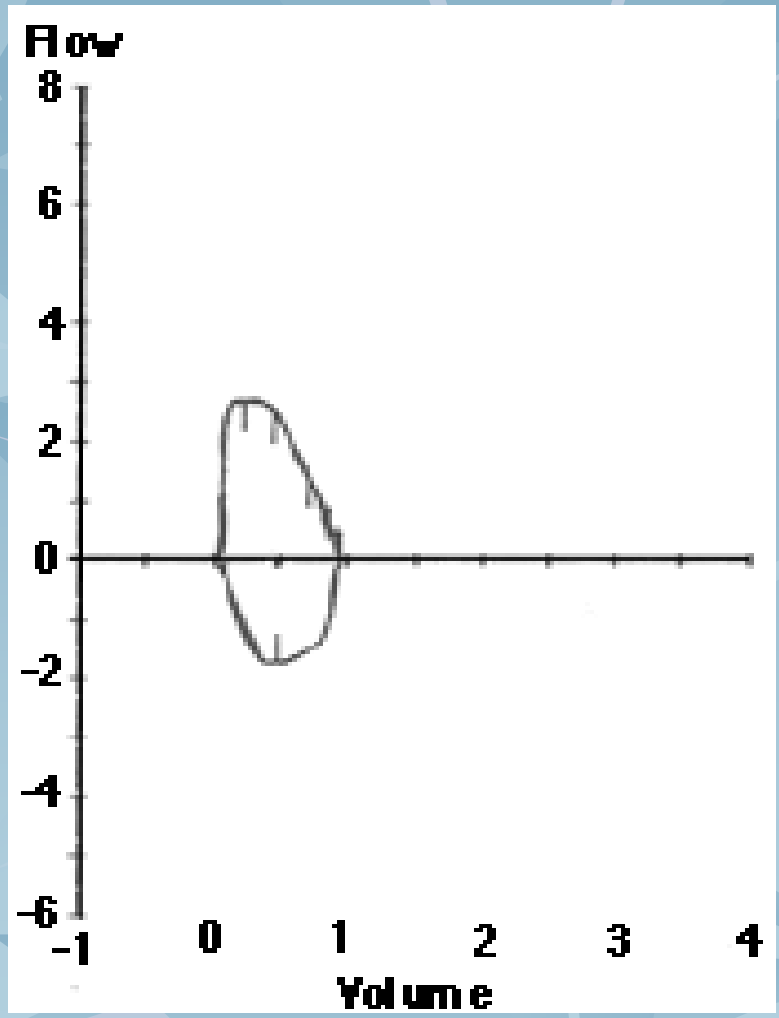
Restrictive Lung Disease

- FVC decreased
- FEV_1 <80% predicted
- FEV_1/FVC (> 85 – 90%)
- Pulmonary – lobar pneumonia, atelectasis, interstitial lung disease (infectious, cystic fibrosis, aspiration, connective tissue disease, vasculitis, pneumonitis, drug induced, malignancy, congenital), pulmonary edema,

  Pleural disease

  Chest Wall (kyphoscoliosis, rib cage anomalies)

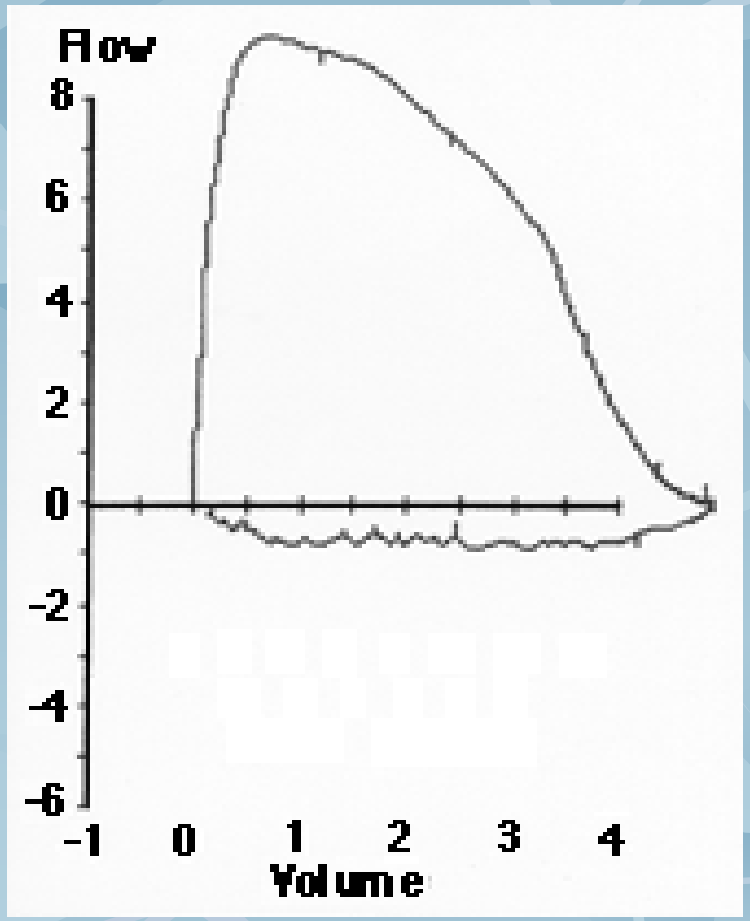
  Neuromuscular disorders
- May need to confirm by measurement of total lung capacity using plethysmography or helium dilution
- technique



Convex shaped expiratory flow loop

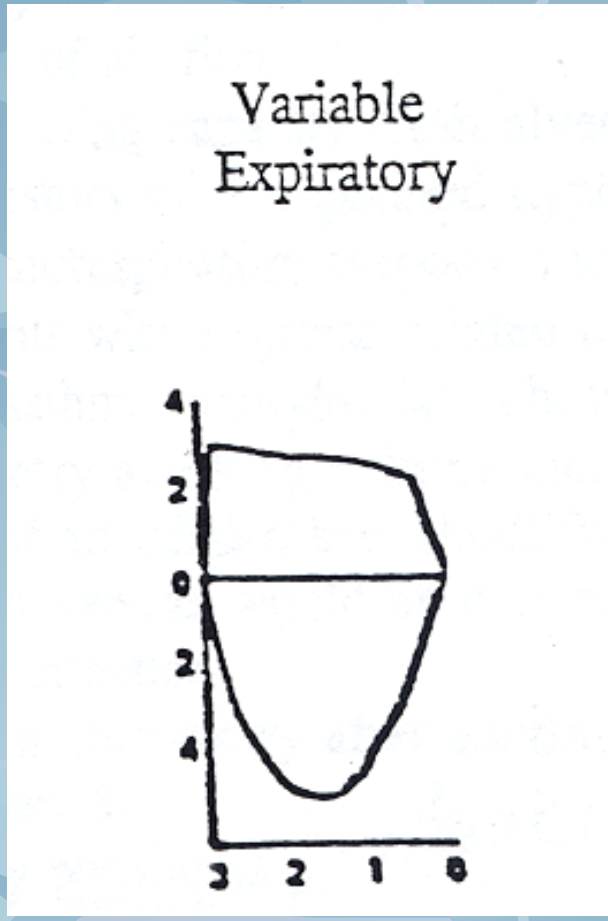
Variable Extrathoracic Obstruction

- On inspiration, airway pressure lower than surrounding atmospheric pressure
- Results in compression at area of obstruction
- Results in chopped inspiratory loop
- Laryngeal edema, malacia, hemangioma, masses, foreign body, vocal cord paralysis, vocal cord dysfunction, extrathoracic tracheomalacia



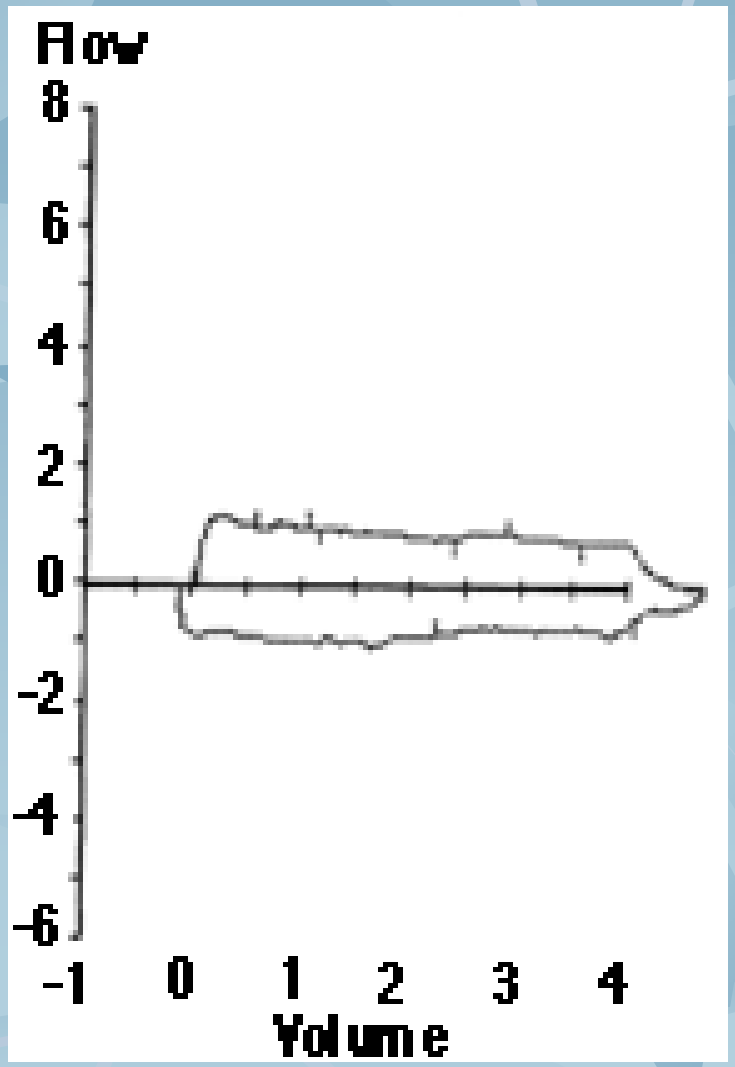
Variable Intrathoracic Obstruction

- On expiration, airway pressure lower than surrounding intrathoracic pressure
- Results in compression at area of obstruction
- Results in chopped expiratory loop
- Intrathoracic tracheomalacia, foreign body, asthma, vascular or mediastinal airway compression



Fixed Intra or Extrathoracic Airway Obstruction

- Results in a chopped inspiratory and expiratory loop
- Subglottic stenosis, proximal tracheal stenosis



Evaluation of Asthma

- Episodic airflow obstruction manifested wheeze, cough, chest pain/tightness or dyspnea and “recurrent bronchitis” or recurrent pneumonia
- Symptoms occur with known asthma triggers and often worse at night
- Patients may have clinical response and spirometry hyper-responsiveness with short-acting beta agonist/bronchodilator
- Practitioners can use pre & post short-acting bronchodilator spirometry, start a 2 to 8 week clinical trial with short-acting bronchodilator, assess clinical response to 2 to 4 week trial of asthma controller therapy (preferably ICS)
- Consideration as necessary to exclude other diagnoses

Why have an Office Spirometry or do it?

- History and physical exam not predictive of lung impairment
  - Often chronic asthma patients have poor perception of symptoms
  - Wheeze not correlative with degree of spirometry impairment

- Preferable to peak flow meters for diagnosis of asthma
  - GINA (Global initiative for asthma) uses peak flow for diagnosis
  - NIH EPR 2007 does not use peak flow for diagnosis

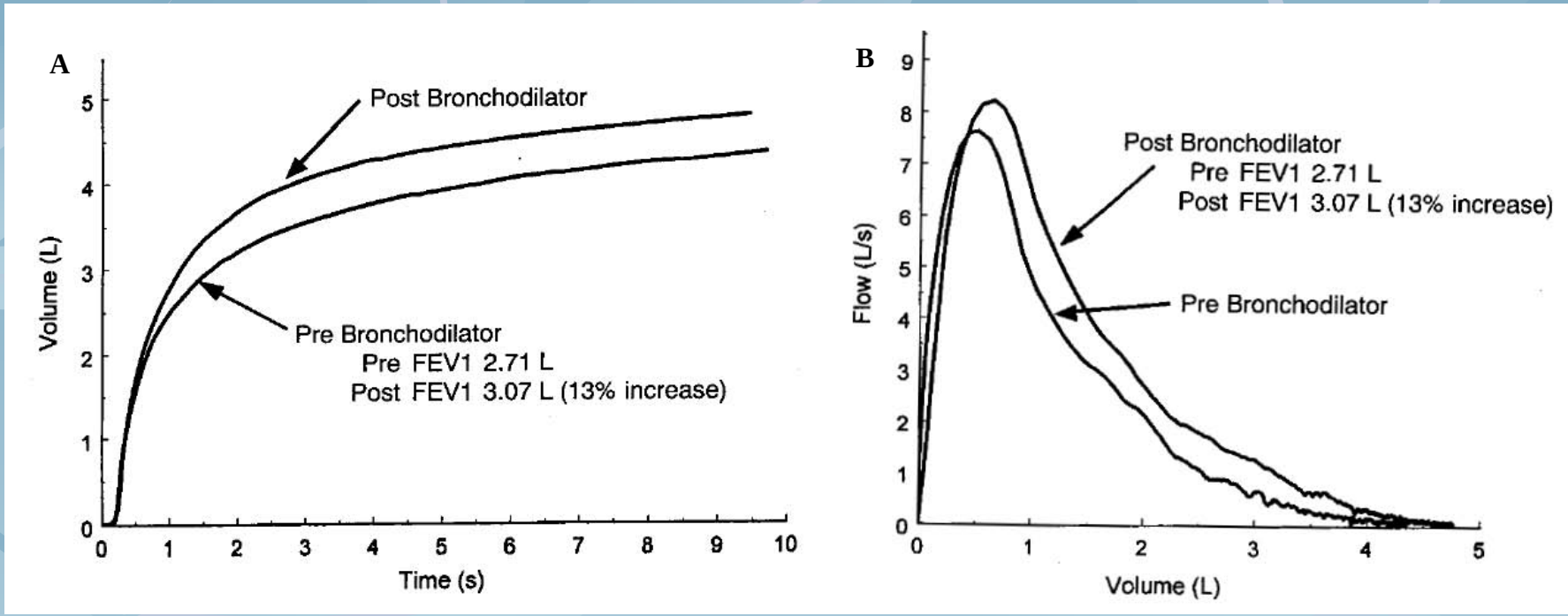
- Useful in excluding other lung disease processes
  - Especially if abnormal and not reversible after short-acting beta agonist
  - or worse with short-acting beta agonist (worry about malacia or bronchiectasis)

Office Spirometry: Bronchial Challenge

- Bronchodilator Response Testing for Asthma
  - Need to use short acting bronchodilator
    2 – 4 puffs of 90mcg/actuation inhaler or nebulizer vial
  - Perform test before and 15 minutes after bronchodilator
  - Positive response is (increase change) ΔFVC or $\Delta FEV_1 > 12\%$ or > 200 ml volume or $\Delta FEF_{25\%-75\%} > 24\%$
  - Changes such as decreased gas trapping or increased partial expiratory flows may be seen in absence of FVC or FEV1 improvement

  Therefore, lack of spirometry hyper-response does not preclude clinical response

Example of Hyper-responsiveness on Spirometry



Spirometry component of the lung function test shows
Forced expiratory lung volume versus time (A) and Forced expiratory flows versus lung volume (B)
(A) 3.07L (post) – 2.71L (pre) divided by 2.71L (pre) = 0.133 or 13% change
This depicts significant response to beta agonist

National Heart, Lung, and Blood Institute, National Asthma Education and Prevention Program: Expert Panel Report 3: Guidelines for the Diagnosis and Management of Asthma, Full Report 2007.

Lung Function Laboratory: Bronchoprovocation Study

- Exercise Challenge

  Treadmill or bicycle exercise for at least 6 to 8 minutes to cause heart rate to be at 80-85% predicted maximum for age

  Lung function changes 5 to 15 minutes <u>after</u> exercise stops

  Positive response is (decrease change) ΔFVC, ΔFEV_1 or ΔPEF by >12 to 15%
- Treadmill is preferable to bicycle for bronchoconstriction response

Lung Function Laboratory: Bronchoprovocation Study

- Methacholine or histamine response
  - 98% of those with symptomatic asthma respond to this
  - Spirometry preformed before and after titrating doses of challenge

    This is typically followed by short acting bronchodilator
  - Positive response is (decreased change) ΔFEV_1 or greater than >20% with small amount of challenge

  Can use cold air, inhaled allergens or particulate matter

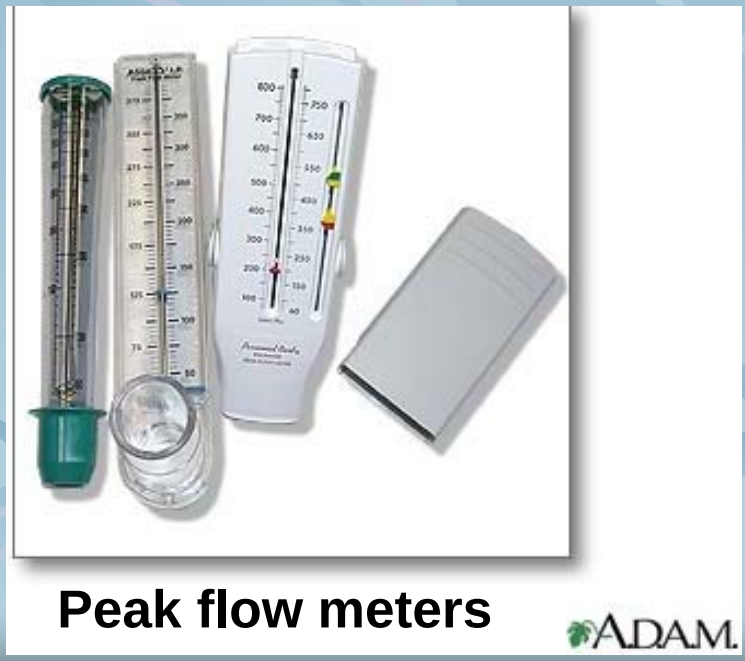
Office Spirometry : Asthma Severity Assessment

- Low FEV1 indicates current obstruction and risk for future exacerbation

-In children FEV1/FVC is a sensitive measure of severity in the impairment domain

- Children with low lung function are at risk for fixed airflow obstruction over time

-Peak flow is not reliable for classifying severity



Peak flow meters

Components of Severity		Classification of Asthma Severity (Children 5-11 years of Age)			
		Intermittent	Persistent		
			Mild	Moderate	Severe
Impairment	Symptoms	≤2 days per week	>2 days/wk but not daily	Daily	Throughout the day
	Nighttime Awakenings	≤2x/month	3-4x/month	≥1x/wk but not nightly	Often 7x/wk
	Short acting beta agonist use for symptom control (not prevention of EIB)	≤2 days per week	>2 days/wk but not daily	Daily	Several times per day
	Interference with normal activity	None	Minor limitation	Some limitation	Extremely limited
	Lung Function	Normal FEV1 between exacerbations FEV1 >80% pred FEV1/FVC >85%	FEV1 ≥80% pred FEV1/FVC >80%	FEV1 = 60 -80%pred FEV1/FVC < 75 -80%	FEV1 < 60%pred FEV1/FVC < 75%
Risk Risk of exacerbation or progressive loss of lung function	Exacerbations requiring oral systemic steroids	0-1 per year	≥2 in one year		
		Consider severity and interval since last exacerbation. Frequency and severity may fluctuate overtime for any patient in any severity category. Relative annual risk of exacerbation may be related to FEV1.			

National Heart, Lung, and Blood Institute, National Asthma Education and Prevention Program: Expert Panel Report 3: Guidelines for the Diagnosis and Management of Asthma, Full Report 2007

Components of Severity		Classification of Asthma Severity (Children ≥12 years of Age)			
		Intermittent	Persistent		
			Mild	Moderate	Severe
Impairment Normal FEV1/FVC: 8-19yo 85% 20-39yo 80% 40-59yo 75% 60-80yo 70%	Symptoms	≤2 days per week	>2 days/wk but not daily	Daily	Throughout the day
	Nighttime Awakenings	≤2x/month	3-4x/month	≥1x/wk but not nightly	Often 7x/wk
	Short acting beta agonist use for symptom control (not prevention of EIB)	≤2 days per week	>2 days/wk but not >1x/day	Daily	Several times per day
	Interference with normal activity	None	Minor limitation	Some limitation	Extremely limited
	Lung Function	Normal FEV1 between exacerbations FEV1 >80% pred FEV1/FVC normal	FEV1 ≥80% pred FEV1/FVC normal	FEV1 = >60 but <80% pred FEV1/FVC reduced 5%	FEV1 < 60%pred FEV1/FVC reduced 5%
Risk	Exacerbations requiring oral systemic steroids	0-1 per year	≥2 in one year		
		Consider severity and interval since last exacerbation. Frequency and severity may fluctuate overtime for any patient in any severity category. Relative annual risk of exacerbation may be related to FEV1.			

National Heart, Lung, and Blood Institute, National Asthma Education and Prevention Program: Expert Panel Report 3: Guidelines for the Diagnosis and Management of Asthma, Full Report 2007

Office Spirometry: Long Term management

-Helpful in assessing control

-Identifies airflow obstruction in “poor perceivers” unable to feel symptoms until severe airflow obstruction

-Tracks disease progression

-Assesses risk of exacerbation, decline in lung function/reduced growth

-Measures response to therapy

-Reinforces therapy decisions to the patient

Components of Control		Classification of Asthma Control (Children 5-11 years of Age)		
		Well Controlled	Not Well controlled	Very Poorly Controlled
Impairment	Symptoms	≤2 days/wk but not more than once on each day	>2 days/wk or multiple times on ≤2 days/wk	Throughout the day
	Nighttime Awakenings	≤1x/month	≥2x/month	≥2x/week
	Short acting beta agonist use for symptom control (not prevention of EIB)	≤2 days per week	>2 days per week	Several times per day
	Interference with normal activity	None	Some limitation	Extremely limited
	Lung Function FEV1 or peak flow FEV1/FVC	 >80% pred/personal best >80%	 60 – 80% pred/personal best 75-80%	 <60% pred/personal best <75%
Risk Risk of exacerbation or progressive loss of lung function	Exacerbations requiring oral systemic steroids	0-1/year	≥2/year	
	Reduction in lung growth Treatment related adverse effects	**Evaluation of reduction in lung growth requires long term follow up Medication side effects can vary in intensity from none to very troublesome and worrisome. The level of intensity does not correlate to specific levels of control but should be considered in the overall assessment of risk.**		

National Heart, Lung, and Blood Institute, National Asthma Education and Prevention Program: Expert Panel Report 3: Guidelines for the Diagnosis and Management of Asthma, Full Report 2007

Components of Control		Classification of Asthma Control (Children ≥12 years of Age)		
		Well Controlled	Not Well controlled	Very Poorly Controlled
Impairment	Symptoms	≤2 days/wk	>2 days/wk	Throughout the day
	Nighttime Awakenings	≤2x/month	1-3x/wk	≥4x/week
	Short acting beta agonist use for symptom control (not prevention of EIB)	≤2 days per week	>2 days per week	Several times per day
	Interference with normal activity	None	Some limitation	Extremely limited
	Lung Function FEV1 or peak flow Validated Questionnaires	>80% pred/personal best	60 – 80% pred/personal best	<60% pred/personal best
Risk Risk of exacerbation or progressive loss of lung function	Exacerbations requiring oral systemic steroids	0-1/year Consider severity and interval since last exacerbation	≥2/year Consider severity and interval since last exacerbation	
	Progressive loss of lung function Treatment related adverse effects	Evaluation of progressive loss of lung function requires long term follow up Medication side effects can vary in intensity from none to very troublesome and worrisome. The level of intensity does not correlate to specific levels of control but should be considered in the overall assessment of risk.		

National Heart, Lung, and Blood Institute, National Asthma Education and Prevention Program: Expert Panel Report 3: Guidelines for the Diagnosis and Management of Asthma, Full Report 2007

Recommended Frequency of Office Spirometry

- At the time of initial assessment
-After treatment is initiated and symptoms and peak flows have stabilized, to document attainment of (near) “normal” airway function
- During a period of progressive or prolonged loss of asthma control
- At least every 1–2 years to assess the maintenance of airway function

May be indicated more often than every 1– 2 years, depending on the clinical severity and response to management

Should be followed to detect potential for decline and rate of decline of pulmonary function over time

National Heart, Lung, and Blood Institute, National Asthma Education and Prevention Program: Expert Panel Report 3: Guidelines for the Diagnosis and Management of Asthma. Full Report 2007

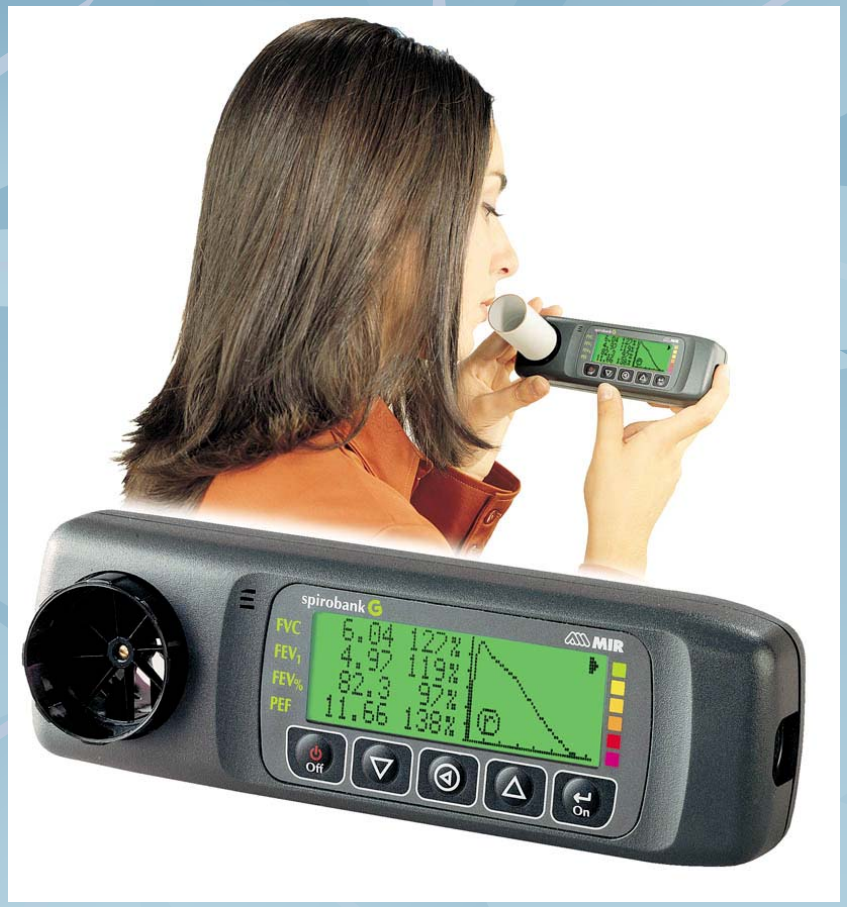
Office & Home Spirometers

KoKo© PC Spirometer

KoKo© Portable Spirometer
$1500

These are not by any means only product available

Office & Home Spirometers



Spirobank G spirometer
Medical International Research
$1300

Piko -1 Somerset Medical LLC

These are not by any means only product available

Abnormal Spirometry Report [redacted] 11/1/2017 9:53:06 AM Page 1

Patient Information:

ID: [redacted]
Name: [redacted]
DOB: [redacted] Age: 11 years
Height: 48 inch Weight: 42.0 lbs
Gender: Female
Race: Caucasian
Packs / Day: _____ Smoke Years: _____
Cooperation: _____

Test Information:

Pre Time: 9:54 AM
Post time: 10:11 AM
Norm Reference: NHANESIII 1999

Quality Messages:

Pre: 6-Good effort, 5-Good effort, 4-Blow out longer, No Plateau, 3-Good effort, 2-Good effort, 1-Blow out longer, No Plateau,
Post: 4-Blow out longer, No Plateau, 3-Good effort, 2-Blow out longer, No Plateau, 1-Good effort,

Test Results: Lung age:
FEV1%Pred: 56 %
FEV1%: 100%
Improvement: FVC: -10%, FEV1: -10% ((Post - Pre) / Pre) * 100
Not Significant BD Response

FEV1 Pre / Post Var. 9 ml (1 %) / 78 ml (10 %)
FVC Pre / Post Var: 9 ml (1 %) / 78 ml (10 %)
ATS Reproducibility:
Pre: MET ()
Post: NOT MET (< 3 acceptable efforts)

Test Interpretation: UNCONFIRMED REPORT

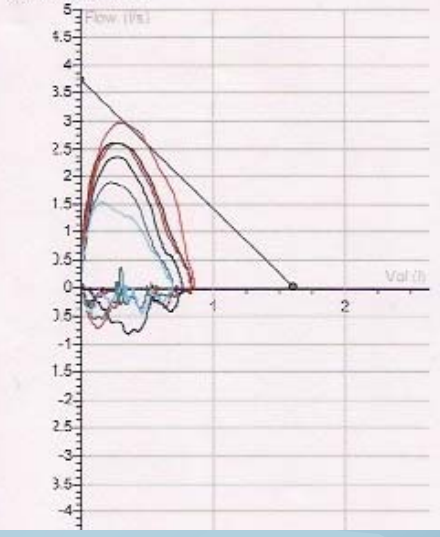
Pre: FVC= 0.85L FEV1= 0.85L
FEV1%= 100.0% 0.85/0.85 FEV1/FVC
(11/1/2017 9:55:08 AM), Moderately severe restriction

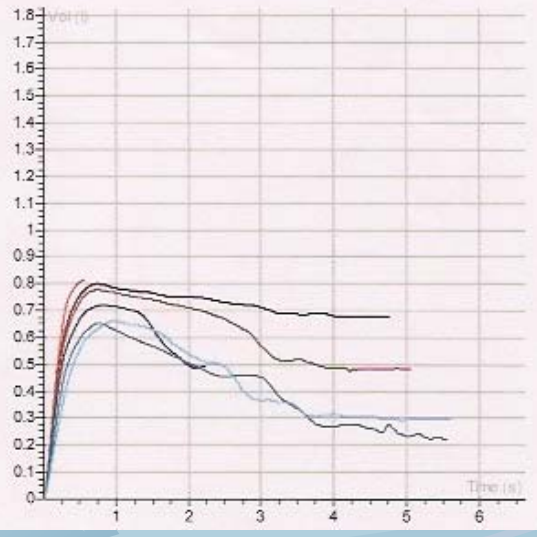
Post: FVC= 0.8L (-9.8%); FEV1= 0.8L (-9.8%); FEV1%= 100.0% (0.0%)
(11/1/2017 10:11:23 AM), Severe restriction

Test Comment:

			Best Effort					Best Three Efforts					
Parameter	Units	Pred	4. Pre	%Pred	2. Post	%Pred	%Change	4. Pre	3. Pre	6. Pre	2. Post	4. Post	3. Post
FVC	(L)	1.61	0.85*	53	0.77*	48	-10% (-0.08)	0.85*	0.84*	0.83*	0.77*	0.69*	0.69*
FEV1	(L)	1.53	0.85*	56	0.77*	50	-10% (-0.08)	0.85*	0.84*	0.83*	0.77*	0.69*	0.69*
FEV1/FVC	(%)	88	100	113	100	113	0% (0)	100	100	100	100	100	100
FEV6	(L)	1.63	0.85*	52	0.77*	47	-10% (-0.08)	0.85*	0.84*	0.83*	0.77*	0.69*	0.69*
PEF	(L/s)	3.74	2.97	79	2.36*	63	-20% (-0.61)	2.97	2.61*	2.61*	2.36*	1.89*	1.54*
FEF25-75	(L/s)	2.42	2.70	112	1.87	78	-31% (-0.83)	2.70	2.14	2.05	1.87	1.59*	1.21*

(*) Means below LLN





This is an 11 year old female with recurrent bronchitis and dyspnea

She had sepsis with multiorgan failure and acute respiratory failure at 5 years old

What pattern is seen on spirometry?

Does she have asthma?

If so, why and what should be considered?

If not why and what other evaluation would one consider?

Abnormal Spirometry Report [redacted] 6/20/2019 9:21:17 AM Page 1

Patient Information:
ID: [redacted]
Name: [redacted]
DOB: [redacted] Age: 11 years
Height: 62 inch Weight: 101.0 lbs
Gender: Female
Race: Caucasian
Packs / Day: _____ Smoke Years: _____
Cooperation: _____

Test Information:
Pre Time: 9:21 AM
Post time: 9:40 AM
Norm Reference: NHANESIII 1999

Quality Messages:
Pre: 4-Good effort, 3-Good effort, 2-Good effort, 1-Good effort.
Post: 3-Good effort, 2-Blow out longer, No Plateau, 1-Good effort.

Test Results: Lung age:
FEV1%Pred: 78 %
FEV1%: 80%
Improvement: FVC: 27%, FEV1: 58% ((Post - Pre) / Pre) * 100
Significant BD Response

FEV1 Pre / Post Var: 22 ml (2 %) / 11 ml (1 %)
FVC Pre / Post Var: 125 ml (6 %) / 294 ml (11 %)
ATS Reproducibility:
Pre: MET ()
Post: NOT MET (< 3 acceptable efforts)

Test Interpretation: UNCONFIRMED REPORT

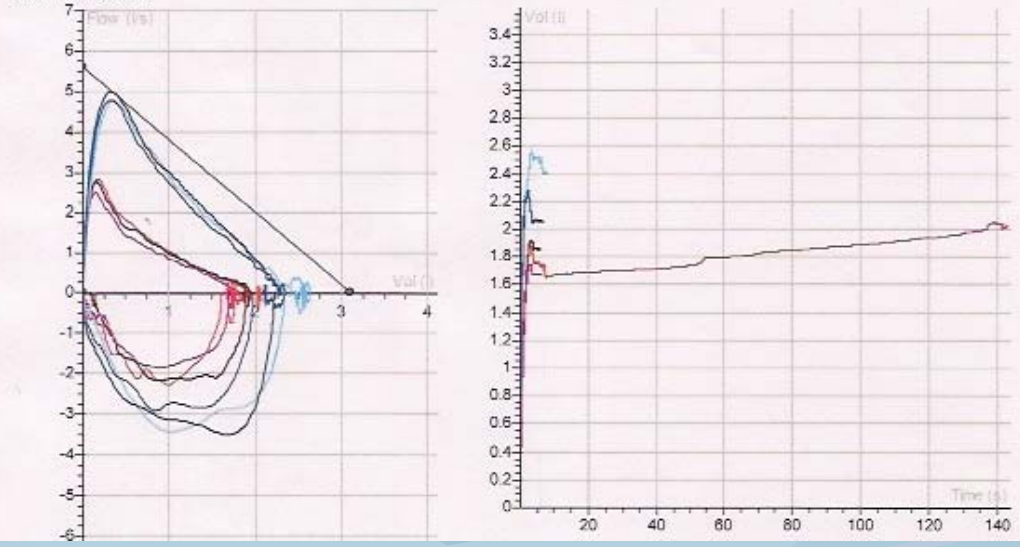
Test Comment:

Pre: FVC= 2.07L FEV1= 1.33L
FEV1%= 64.4% 1.33/2.07 FEV1/FVC
(6/20/2019 9:22:50 AM), Severe obstruction.Moderate restriction

Post: FVC= 2.6L (27.1%); FEV1= 2.1L (57.7%); FEV1%= 79.9% (24.1%)
(6/20/2019 9:41:12 AM), Within normal limits

			Best Effort					Best Three Efforts					
Parameter	Units	Pred	4. Pre	%Pred	3. Post	%Pred	%Change	4. Pre	3. Pre	2. Pre	3. Post	2. Post	1. Post
FVC	(L)	3.09	2.07*	67	2.63	85	27% (0.56)	2.07*	1.94*	1.76*	2.63	2.27*	2.34*
FEV1	(L)	2.68	1.33*	50	2.10*	78	58% (0.77)	1.33*	1.31*	1.21*	2.10*	2.11*	2.03*
FEV1/FVC	(%)	88	64	73	80	90	24% (16)	64	67	69	80	93	87
FEV6	(L)	3.08	1.90*	62	2.63	86	38% (0.73)	1.90*	1.94*	1.76*	2.63	2.27*	2.34*
PEF	(L/s)	5.60	2.81*	50	4.77	85	70% (1.96)	2.81*	2.75*	2.48*	4.77	4.97	4.78
FEF25-75	(L/s)	3.11	0.85*	27	1.90*	61	122% (1.04)	0.85*	0.92*	0.92*	1.90*	2.48	2.09

(*) Means below LLN



This is an 11 year old female diagnosed with asthma. Mother says child has no symptoms

What pattern is seen on spirometry?

Does she have asthma?

If so, why and what should be considered?

If not why and what other evaluation would one consider?

Abnormal Spirometry Report [redacted] 3/2/2018 9:31:58 AM Page 1

Patient Information:

ID: [redacted]
Name: [redacted]
DOB: [redacted] Age: 17 years
Height: 69 inch Weight: 125.0 lbs
Gender: Male
Race: Caucasian
Packs / Day: _____ Smoke Years: _____
Cooperation: _____

Test Information:

Pre Time: 9:32 AM
Post time: 10:04 AM
Norm Reference: NHANESIII 1999

Quality Messages:

Pre: 3-Blast out faster, 2-Blast out faster, 1-Blast out faster,
Post: 3-Blast out faster, 2-Blast out faster, 1-Do not hesitate,

Test Results: Lung age:
FEV1%Pred: 58 %
FEV1%: 73%
Improvement: FVC: -6%, FEV1: -4% ((Post - Pre) / Pre) * 100
Not Significant BD Response

FEV1 Pre / Post Var: 1 ml (0 %) / 153 ml (7 %)
FVC Pre / Post Var: 118 ml (3 %) / 26 ml (1 %)
ATS Reproducibility:
Pre: MET ()
Post: NOT MET (< 3 acceptable efforts)

Test interpretation: UNCONFIRMED REPORT

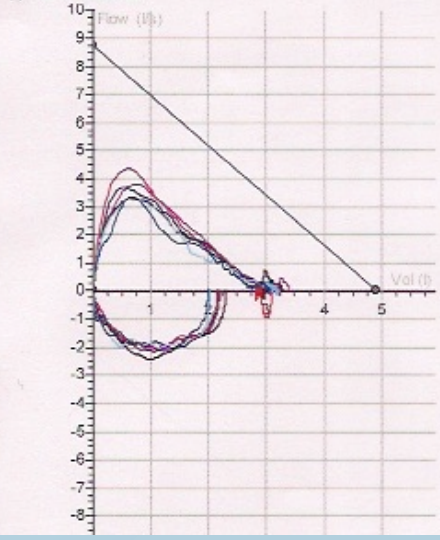
Test Comment:

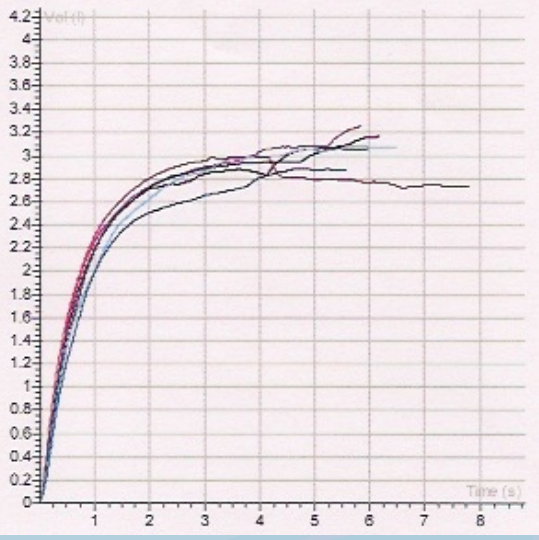
Pre: FVC= 3.39L FEV1= 2.40L
FEV1%= 70.8% 2.40/3.39 FEV1/FVC
(3/2/2018 9:32:37 AM), Moderately severe obstruction Moderate restriction

Post: FVC= 3.2L (-6.4%); FEV1= 2.3L (-3.9%); FEV1%= 72.7% (2.7%)
(3/2/2018 10:05:17 AM), Moderately severe obstruction Moderate restriction

			Best Effort					Best Three Efforts					
Parameter	Units	Pred	2. Pre	%Pred	2. Post	%Pred	%Change	2. Pre	3. Pre	1. Pre	2. Post	3. Post	1. Post
FVC	(L)	4.91	3.39*	69	3.18*	65	-6% (-0.22)	3.39*	3.28*	3.08*	3.18*	3.20*	3.05*
FEV1	(L)	4.17	2.40*	58	2.31*	55	-4% (-0.09)	2.40*	2.30*	2.40*	2.31*	2.13*	2.16*
FEV1/FVC	(%)	85	71	84	73	86	3% (2)	71	70	78	73	66	71
FEV6	(L)	4.90	3.39*	69	3.18*	65	-6% (-0.22)	3.39*	3.27*	3.08*	3.18*	3.20*	3.05*
PEF	(L/s)	8.74	3.81*	44	3.70*	42	-3% (-0.11)	3.81*	3.27*	4.38*	3.70*	3.31*	3.34*
FEF25-75	(L/s)	4.45	1.67*	38	1.80*	40	8% (0.13)	1.67*	1.73*	2.08*	1.80*	1.52*	1.65*

(*) Means below LLN





This is an 17 year old male with chronic productive cough and dyspnea.

What pattern is seen on spirometry?

Does he have asthma?

If so, why and what should be considered?

If not why and what other evaluation would one consider?

Normal Spirometry Report [redacted] 6/20/2019 10:48:15 AM Page 1

Patient Information:

ID: [redacted]
Name: [redacted]
DOB: [redacted] Age: 5 years
Height: 44 inch Weight: 58.0 lbs
Gender: Female
Race: Hispanic
Packs / Day: _____ Smoke Years: _____
Cooperation: _____

Test Information:

Pre Time: 10:48 AM
Post time: 11:06 AM
Norm Reference: Polgar 1971

Quality Messages:

Pre: 7-Good effort, 6-Good effort, 5-Good effort, 4-Good effort, 3-Good effort, 2-Good effort, 1-Blow out longer, No Plateau.
Post: 7-Good effort, 6-Good effort, 5-Blast out faster, 4-Blast out faster, 3-Good effort, 2-Good effort, 1-Good effort,

Test Results: Lung age:
FEV1%Pred: 82 %
FEV1%: 86%
Improvement: FVC: 17%, FEV1: 15% ((Post - Pre) / Pre) * 100
Not Significant BD Response

FEV1 Pre / Post Var: 52 ml (6 %) / 31 ml (3 %)
FVC Pre / Post Var: 111 ml (12 %) / 128 ml (12 %)
ATS Reproducibility:
Pre: NOT MET (FVC and/or FEV1 Variance > 150 ml)
Post: NOT MET (FVC and/or FEV1 Variance > 150 ml)

Test interpretation: UNCONFIRMED REPORT

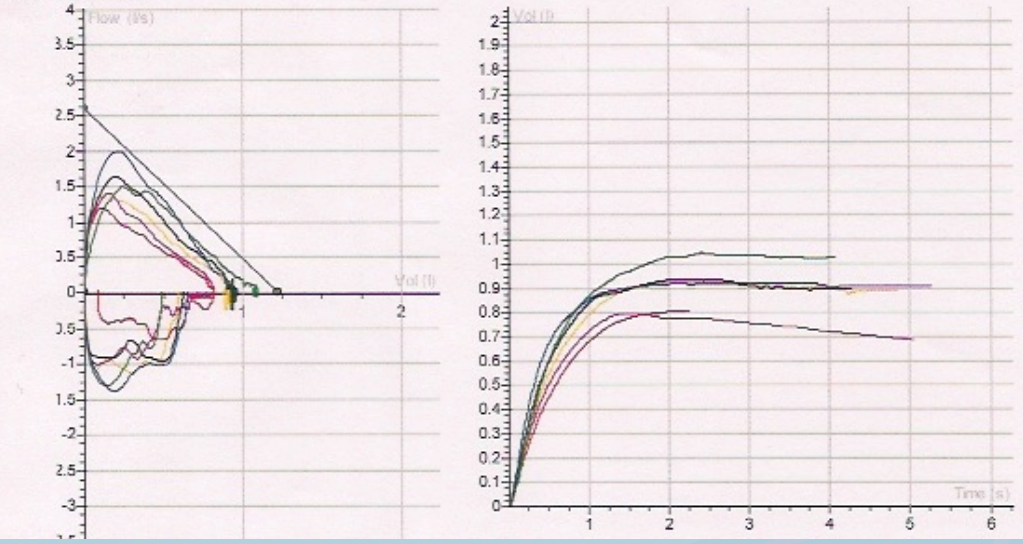
Test Comment:

Pre: FVC= 0.93L FEV1= 0.80L
FEV1%= 85.9% 0.80/0.93 FEV1/FVC
(6/20/2019 10:49:40 AM), Within normal limits

Post: FVC= 1.1L (17.5%); FEV1= 0.9L (14.7%); FEV1%= 83.9% (-2.4%)
(6/20/2019 11:07:29 AM), Within normal limits

		Best Effort						Best Three Efforts					
Parameter	Units	Pred	7. Pre	%Pred	5. Post	%Pred	%Change	7. Pre	2. Pre	1. Pre	5. Post	1. Post	7. Post
FVC	(L)	1.22	0.93	76	1.09	89	17% (0.16)	0.93	0.82*	0.82*	1.09	0.95	0.96
FEV1	(L)	1.11	0.80*	72	0.91*	82	15% (0.12)	0.80*	0.75*	0.70*	0.91*	0.88*	0.87*
FEV1/FVC	(%)	-	86	-	84	-	-2% (-2)	86	91	85	84	93	90
FEV6	(L)	-	0.93	-	1.09	-	17% (0.16)	0.93	0.82	0.82	1.09	0.95	0.96
PEF	(L/s)	2.61	1.37*	53	1.50*	58	9% (0.13)	1.37*	1.41*	1.20*	1.50*	2.00	1.65*
FEF25-75	(L/s)	1.39	0.81	58	0.96	69	18% (0.14)	0.81	0.80	0.68	0.96	1.18	0.95

(*) Means below LLN



This is a 5 year old female with recurrent pneumonia.

What pattern is seen on spirometry?

Does she have asthma?

If so, why and what should be considered?

If not why and what other evaluation would one consider?

- **Vocal Cord Dysfunction (VCD)**

  - Paradoxical adduction of the vocal cords on inspiration
  - Characterized by tightness, wheezing, stridor and dyspnea
  - Often treated for refractory asthma with inhaled and systemic corticosteroids
  - History of ED or urgent care visits and hospital admissions
  - May undergo intubation or tracheostomy
  - Predominantly female
  - One retrospective study found 10% of patients with intractable asthma had VCD and 30% had VCD coexisting with asthma

Vocal Cord Dysfunction Pathophysiology

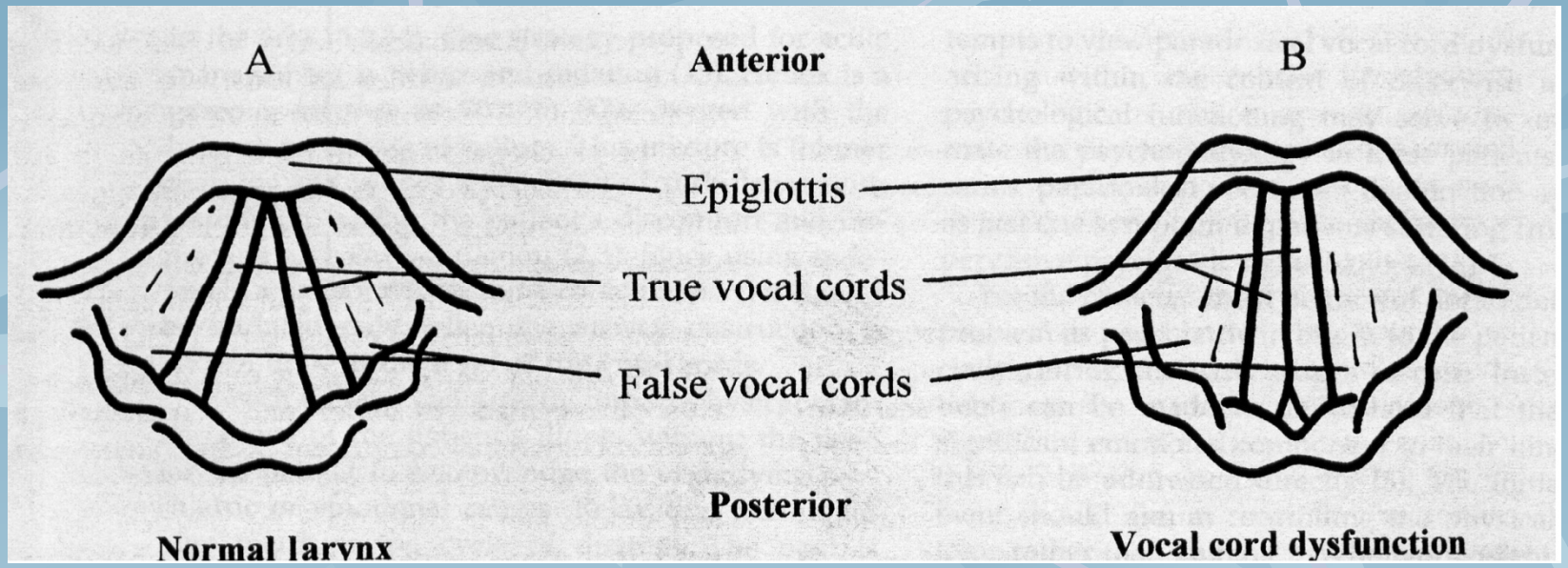
- Pathogenesis not fully understood

- Intrinsic and extrinsic stimulation causing hyperresponsiveness of laryngeal sensory and motor innervation
- Alteration of vagal mediated laryngeal tone

- Possible stimulants identified
  Irritants (chemical cleaners, organic solvents, smoke) may alter vagal laryngeal tone lowering threshold for inspiratory adduction
  GERD may accentuate glottic closure due to acid injury of laryngeal mucosa
  Emotional stress, anxiety
- Although rarely a cause, neurologic conditions such as Chiari malformation, cerebrovascular accident, or brainstem injury should be considered

Clinical Presentation	
VCD	Asthma
Tightness at the neck (extratoracic)	Tightness at the chest (intrathoracic)
Stridor/wheeze, voice change, difficult inspiration globus sensation	Wheeze, dyspnea
Abrupt beginning and end	Symptoms prolonged
Occurs primarily during day while awake	Diurnal pattern (increased nocturnally)
Resolve with relaxation Albuterol no relief	Relieved with beta agonist
Occurs soon after exercise	Starts within 5 to 15 minutes of exercise and increases steadily

Findings	
VCD	Asthma
Displays “La Belle Indifference” or distress	Displays distress
Wheezing/stridor loudest over neck	Wheeze loudest peripherally in chest
Can hold breath during event	Unable to hold breath during event
No cyanosis or hypoxia	May have cyanosis, hypoxia
Normal blood gas; no alveolar arterial gradient	May have A-a gradient and hypercapnea
Chest xray normal	Hyperinflated, atelectasis, peribroncial thickening

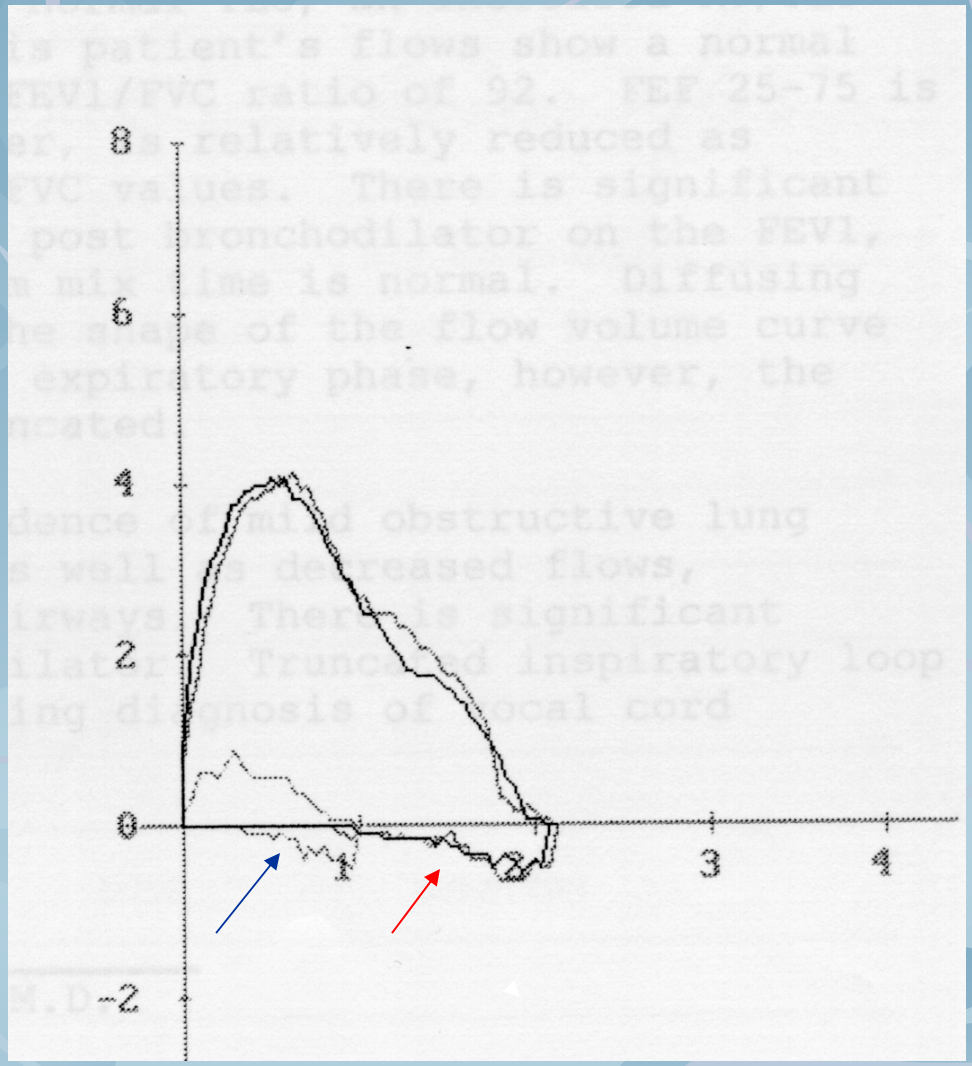


Picture A True vocal cords are abducted during inspiration in normal larynx

Picture B Noted adduction of the true vocal cords anterior during inspiration with posterior diamond shaped opening

Place R et al Journal of Adolescent Health 2000

Spirometry Findings



The blunted inspiratory loop is seen both on tidal breathing (blue) and forced inspiration (red). Patient J.D. 1/2003

Vocal Cord Dysfunction Management

- Recognition and diagnosis of disease and possible stimulant mechanism

- Anti-anxiolytic therapy, mood disorder therapy, psychotherapy
- Recognition and treatment for GERD
- Although rare, awareness of possible neurologic disease

- Speech therapist who is experienced with VCD
  Relaxed throat breathing techniques

Conclusion

- Office spirometry is preferred to peak flow in diagnosing and establishing asthma severity
- Office spirometry is useful for maintaining asthma control and detecting decline in lung function
- Lung function FEV1 can predict asthma severity, risk of exacerbation and loss of lung function/growth

References

- Pattishall EN. Pulmonary function testing reference values and interpretations in pediatric training programs. Pediatrics 1990: 85:768-773.

- Sly PD et al A Review of pulmonary function testing in children. Journal of asthma 1990: 27:137-147

- Mueller GA and Eigen H. Pulmonary function testing in the pediatric practice. Pediatrics in Review 1994:15:403-411.

- Eigen H. Pulmonary function testing: a practical guide to its use in pediatric practice. Pediatrics in Review 1986:7:235-246.

- Voter KZ and McBride JT. Diagnostic tests of lung function. Pediatrics in Review 1996:17:53-63.

- Pellegrino R et al. Interpretative strategies for lung function tests. Eur Respir J 2005; 26: 948–968

References

- Miller MR et al. General considerations for lung function testing. Eur Respir J 2005; 26: 153–161

- Beydon N et al. An Official American Thoracic Society/European Respiratory Society Statement: Pulmonary Function Testing in Preschool Children. Am J Resp Crit Care Med 2007

- National Heart, Lung, and Blood Institute, National Asthma Education and Prevention Program: Expert Panel Report 3: Guidelines for the Diagnosis and Management of Asthma, Full Report 2007
  Major reference which can be accessed via the NIH-NHLBI website at http://www.nhlbi.nih.gov/guidelines/asthma/index.htm in pdf format

- George, S and Suresh S. Vocal Cord Dysfunction: Analysis of 27 Cases and Updated Review of Pathophysiology & Management. Internat Arch Otorhino 2019