Pulmonary Function Testing: Quick Review

CRC 431 – Cardiopulmonary Physiology & Disease
Bill Pruitt, MBA, CPFT, RRT, AE-C
Resources

- Wilkins Assessment 7th ed Ch 9 (Read first)
- Egan Fundamentals 10th ed Ch 19
- White Competencies 5th ed Ch 5
  - (Supplemental text: Ruppel’s Manual of Pulmonary Function Testing 10th ed- Carl Mottram)
- Lecture notes

- Youtube
- “Basic Interpretation of PFT” by PJSMDPete
  1. 19:50 Spirometry
  2. 15:12 Volumes and Diffusion
  3. 9:26 Pitfalls and abnormalities (??)
  4. 15:25 Practice
4 Capacities, 4 volumes

Changes in lung volumes and capacities with pulmonary disease.
Key Determinants of Predicted Values

• **Age** - values decrease with age
• **Height** - values increase with height
• **Sex** - females have smaller lungs = less volume

• **Race/Ethnicity** also influences predicted values
  – (sometimes called reference values)

• Reports given with Measured, Predicted, and Percent predicted. Example:
  
  • FVC Meas = 4.71 Pred = 5.28, % Pred = 89
• Note – use arm span if height is not measurable
## Example

<table>
<thead>
<tr>
<th>Value</th>
<th>Meas (L)</th>
<th>Pred (L)*</th>
<th>% Pred</th>
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<tr>
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<td>4.71</td>
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<td>92</td>
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<tr>
<td>FEV$_1$</td>
<td>3.05</td>
<td>3.91</td>
<td>78</td>
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<tr>
<td>FEV$_1$/FVC</td>
<td>65</td>
<td>77</td>
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Note: FEV$_1$ ratio is 65 (abnormal), and the FEV$_1$ % predicted is 78 (normal)

*The most commonly used predicted or reference comes from NHANES 3

Note that there is growing support for using “lower limits of normal” instead of 80% as the threshold for what is normal versus abnormal
Other Influencing Factors

• **Weight** (ideal body weight vs actual weight)
  - BMI <18.5: below normal weight
  - BMI 18.5 – 25: normal weight
  - BMI 25 – 30: overweight
  - BMI 30 – 35: Obese Class I
  - BMI 35 – 40: Obese Class II
  - BMI >40: Obese Class III (Extreme obesity or morbid obesity)

• **Environment** (ie. air pollution, altitude)

• **Smoking**
  - See nomograms for males/females on page 92 in White’s Lab Competencies. Also Wilkins pg. 144
Withholding Medications

Before performing spirometry, withhold:

✓ Short acting $\beta_2$-agonists for 6 hours
✓ Long acting $\beta_2$-agonists for 12 hours
✓ Anticholinergics
  ✓ Ipratropium for 6 hours
  ✓ Tiotropium for 24 hours

Optimally, subjects should avoid caffeine and cigarette smoking for 30 minutes before performing spirometry
Spirometry Quality Control – 6 points

At least 3 tests and:

1. Acceptable tests have no hesitation ...BEV < 5% of FVC (this is the start of test)
2. Acceptable tests have at least 6 seconds for exhalation (this is the middle of test) (but don’t stop until.......)
3. Acceptable tests reach a plateau (this is the end of test for recording exhalation)

4. The 2 best tests FVC values + 150 ml
5. The 2 best FEV$_1$ values + 150 ml
6. The best 2 acceptable tests PEF + 10%

1, 2, 3 are “within” test criteria; 4, 5, 6 are “between” tests
ATS recommends doing up to 8 repeated tests.... then stop trying
Spirometry - Possible Side Effects

- Feeling light-headed
- Headache
- Getting red in the face
- Fainting: reduced venous return or vasovagal attack (reflex)
- Transient urinary incontinence

Spirometry should be avoided after recent heart attack or stroke
Before and After Bronchodilator Therapy
(Pre & post bronchodilator)

• Indication: $\text{FEV}_1$ ratio is less than predicted
• Patient should hold meds that could “blunt” the spirometry
  – Hold quick-acting bronchodilators at least 4 hours prior to testing (if possible), long lasting at least 12 hours

• Record baseline (pre) F/V loops and lung volumes (lung subdivisions) before giving bronchodilator.
• Give tx and wait 15 minutes before retesting F/V loops
Before and After Bronchodilator Therapy  
(Pre & post bronchodilator)

• To be called “Significant response to bronchodilator”
  – (+) 12% change and 200 cc increase in $\text{FEV}_1$
  – This is the most “favored” change
 .................................................. OR  ..................
  – (+) 12% change and 200 cc increase in FVC

• % Change = \[
\frac{\text{Post} - \text{Pre}}{\text{Pre}} \times 100
\]
  – Expectation is for increased FVC and $\text{FEV}_1$ post tx
  • Note: Decreased volume (FVC) in post measurements could be related to fatigue
Pre-post F/V loops and V/T curves
### PULMONARY FUNCTION ANALYSIS

#### Spirometry

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<tr>
<th>Test</th>
<th>Unit</th>
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<th>Pre Meas</th>
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# Pulmonary Function Analysis

## Spirometry

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Note: Imagine the predicted image F/V Loop

<table>
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![Graphs showing volume and flow over time]
MVV
(Maximum voluntary ventilation)

• Measures deep and rapid breathing over 12 to 15 seconds
• Rate > 60 (one breath per second)
• Goal is to reach or exceed best FEV$_1$ x 40 for indication of patient effort (some use 35)
• Marked reduction reflects higher post-op risks for abdominal and thoracic surgery patients
MVV Recording
Volume \times rate

Amount of air moved in 12 seconds
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**Diagram:**

- **Y-axis:** Volume
- **X-axis:** Time
- Graphs showing volume over time with two lines representing different conditions.

**Legend:**

- MVV
- Graph lines indicating volume changes over time.
Nitrogen Washout Test

• Assumptions
  – $N_2$ in the lungs is assumed to be 78%
  – Each minute of $O_2$ breathing 30 - 40 ml are washed out from blood and tissues
• $FRC \times N_2\%\ start = \ Expired\ volume \times N_2\%\ end$
  Solve for FRC

• $FRC - ERV = RV$

• Breathing 100% $O_2$: wash $N_2$ down to <1.5% x 3 then stop test
Nitrogen washout... then

Nitrogen washout... now
N₂ Washout

N₂  78%

FRC  0.0

100% oxygen goes in

ERV

SVC

Analyze N₂ with each exhaled breath
Nitrogen Washout Recording
Nitrogen Washout Test

• Current Method
  – rapid $N_2$ Analyzer with spirometer
  – breath-by-breath graphic display of $\%N_2$ vs accumulated volume

• MUST MEASURE $N_2$ AND ACCUMULATED VOLUME TO GET FRC

• Discuss the bath tub illustration
Helium Dilution Test

• Technique
  – Test starts with subject at resting end-expiratory level (at FRC)… just like the N₂ washout
  – Subject breathes from a spirometer system containing ~ 10% He (closed circuit)
  – The subject rebreaths air but water and CO₂ are absorbed and O₂ is added as it is being consumed.
  – Test halted when He % is constant (plateau at ± 0.02% for 30 seconds); 2 to 5 minutes if healthy, longer if COPD
Helium Dilution Test

• Assumptions
  – He does not readily cross the A/C membrane
  – 100 ml is usually subtracted from the determined FRC
Helium Dilution Measurement
Helium Dilution

Test halted when He % is constant (plateau at $\pm 0.02\%$ for 30 seconds);
Gas Analysis Methods

• Helium dilution and Nitrogen washout have certain errors and problems
  – Leaks make the measurements worthless ... stop the test
  – Good measurement depends on all parts of lung being well ventilated
  – Both methods may underestimate FRC in severe obstruction due to poor gas communication with the trapped gas (if you don’t measure it, you don’t know it’s there –eh?)
Body Plethysmography

Fig. 7–8 Measurement of airway resistance (Raw) by body plethysmograph. \( \dot{V} = \) ventilation; \( P_A = \) airway pressure; \( P_F = \) pressure. (From Scanlon CL, Spearman CB, and Sheldon RL: Egan's fundamentals of respiratory therapy, ed 5, St L Mosby-Year Book.)
Body Plethysmography

• Technique
  – $R_{AW}$ measured first with shutter open, then $V_{TG}$ is measured with shutter closed (this is used to determine FRC)
  – Test starts with subject at resting end-expiratory level (FRC) Shutter closes at zero flow.
  – Subject pants against a closed shutter at rate of 1 Hz.
  – Changes in pressure reflect changes in volume in the thorax and the box. (Boyle’s Law)
  – Subject holds hands against cheeks to prevent pressure changes in the mouth due to inflation of the cheeks.
Plethysmography

ERV

SVC

F1 and start "panting"

Shutter starts open (Raw) then closes (Vtg)
Body Plethysmography

- Relies on Boyle’s gas law which states that volume and pressure vary inversely if temperature is held constant.
  - \( P_1 \times V_1 = P_2 \times V_2 \)
  - \( V_1 = (P_2 \times V_2)/ P_1 \)

- The pressure measured is a combination: mouth, box
- The volume measured is from the box, and the unknown volume (FRC)
Body Plethysmography

• Measures Thoracic Gas Volume ($V_{TG}$)
  
  • $V_{TG}$ may be larger than FRC if there is gas trapped in the body (pneumothorax, abdominal gas) but this is rare!

• FRC should match $V_{TG}$ for reliable start of test (shutter should close at end of exhalation or at FRC)

• More accurate than $N_2$ washout or Helium dilution.... body box measures all the volume trapped in the lungs during the panting maneuver
Carbon Monoxide Diffusing Capacity

• Measures how quickly gases move across the alveolar-capillary (a-c) membrane

• Sometimes called “Transfer factor”

• Abbreviation – DLCO_{SB} referring to “diffusion in the lung of carbon monoxide in a single breath”

• Interpretation uses DLCO/VA where VA = alveolar volume (this is measured by tracer gas – usually methane)
Carbon Monoxide Diffusing Capacity

• Gas exchange measurement is effected by:
  – diffusion coefficient of the gas used in testing
  – surface area of the a-c membrane
  – thickness of the a-c membrane
  – blood volume in the pulmonary capillaries
  – distribution of inspired gas
  – hemoglobin (results are adjusted for anemia)
Carbon Monoxide Diffusing Capacity

- Average normal DLCO is 25 ml CO/min/mmHg.
- Emphysema destroys alveoli and thus reduces surface area and distribution of gas = decreased DLCO and DLCO/VA.
- Restrictive diseases [ie interstitial diseases ("osis") ] reduce lung volume and tend to thicken the A/C membrane = decreased DLCO and DLCO/VA.
- Blood volume in the capillaries... think “pulmonary embolism”
- Bronchitis reduces “raw” DLCO but leaves alveoli intact for gas exchange, so the DLCO/VA will be normal.
Carbon Monoxide Diffusing Capacity

• Low capillary blood volume (or PE), low hemoglobin, and increased COHb reduce the diffusion. (Correcting for low hemoglobin and/or COHb will increase the DLCO)

• Bronchitis doesn’t typically affect alveoli structures or volumes, so DLCO will be normal unless there is a markedly abnormal V/Q
Top line at the split – methane (CH4), bottom line carbon monoxide (CO)
Technique for DLCO$_{SB}$

- If possible... measure hemoglobin to get results corrected for Hb issues (polycythemia or anemia) and measure the COHb (high levels will “blunt” raw measurement)
  - This correction shows up in the DL$_{ADJ}$
- Subject takes in a single breath of the gas source (CO and tracer gas)
  - Inspired volume should be 90% of best FVC
  - Holds breath to 9-11 seconds then exhales
- Measures CO and tracer gas after first 750 cc (tracer can be helium or methane)... discard volume
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<tr>
<td>DLCO Date</td>
<td>11/03</td>
<td></td>
<td></td>
<td>11/03</td>
<td>11/03</td>
</tr>
</tbody>
</table>
DLCO_{SB}  
Tips and points to consider  
• What happens with breath hold of 14 seconds?  
• What happens with valsalva maneuver?  
• What if the patient just smoked a cigarette?  
• How does exercise affect DLCO_{SB}?
Severity of Abnormality

- Normal: >80% predicted *  
- Mild: 65 - 80% predicted  
- Moderate: 55 - 65% predicted  
- Severe: 35 - 55% predicted  
- Very severe: < 35% predicted  

* except for FEV₁/FVC (>70%)
General Interpretation for Complete PFT Exam

• Spirometry – Key is the FEV$_1$% 
  – If FEV$_1$ ratio is below predicted
    (or below 70%) = Obstruction
    AND Pre and post bronchodilator is indicated
      – Note distinction of FEV$_1$% versus FEV$_1$% predicted

----------------------------------

– Not held in high favor…. Not “diagnostic”
  • FEF$_{25-75\%}$ below predicted - small airways
  • FEF$_{200-1200}$ below predicted - medium/ large airways
General Interpretation for Complete PFT Exam

• Lung subdivisions
  A. TLC < 80% predicted and all other volumes reduced proportionally = restriction
  
  A. RV, FRC, and RV/TLC increased = air trapping
  B. If airtrapping continues and grows, retrosternal air develops and you move into hyperinflation
  C. TLC > 95% predicted = probable hyperinflation
General Interpretation for Complete PFT Exam

- Diffusion (DLCO) results should be examined with spirometry and lung volumes in mind.
- \( \frac{DLCO}{V_A} \) used for interpretation (alveolar volume)

A. \( \frac{DLCO}{V_A} \) low + obstruction (airtrapping, hyperinflation?) = emphysema
B. \( \frac{DLCO}{V_A} \) low + restriction (all volumes reduced) = fibrosis
C. \( \frac{DLCO}{V_A} \) normal + obstruction (airtrapping, hyperinflation?) = bronchitis
D. \( \frac{DLCO}{V_A} \) low + no lung obstruction or restriction = low hemoglobin, decreased blood flow (PE)
Bronchial Provocation

• Trying to induce bronchospasm... evaluate for “twitchy airways”
  – No bronchodilators, antihistamines, coffee, tea, chocolate (methylxanthines and theobromines)
  – Do a complete PFT - must be free of air flow obstruction (AFO)
  – Bland aerosol to start to check for reaction F/V loop at 30 seconds and 90 seconds.
Bronchial Provocation

• Low dose of *methacholine (provacholine) inhaled.

• Progressively increase if negative.
  • Start at 0.025mg/ml, 0.25 mg, 2.5mg, 10mg, up to 25mg. Positive response is a 20% decrease in FEV\textsubscript{1}

• Finish with a bronchodilator - FEV\textsubscript{1} must be within 5% of baseline to go home

*Histamine has also been used in other countries
Bronchial Provocation

• The absence of airways obstruction does not rule out asthma.
  – (Normal spirometry?)
• A negative response to bronchial provocation does.
• A positive response is not totally clear but adds to the pieces that say “asthma” (COPD, sinusitis may be positive)
• OR – if you have asthma, you have “twitchy” airways that will react to provocation. No response? no asthma.
Bronchial challenge testing

PC 20 FEV1  0.109
# Bronchochallenge Report

**Protocol: ATS_Methacholine(2)**

<table>
<thead>
<tr>
<th>Dose</th>
<th>Ref Meas</th>
<th>Pre Baseline Meas</th>
<th>Level 1 Meas</th>
<th>Level 2 Meas</th>
<th>Level 3 Meas</th>
<th>Level 4 Meas</th>
<th>Level 5 Meas</th>
<th>Level 6 Meas</th>
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<tr>
<td>FVC Liters</td>
<td>3.17</td>
<td>4.23</td>
<td>4.25</td>
<td>4.27</td>
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<tr>
<td>% Ref</td>
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<td>79</td>
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<td>130</td>
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<tr>
<td>% Chg</td>
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<td>FEV1 Liters</td>
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<td>3.59</td>
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<td>% Ref</td>
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<td>FEF25-75%</td>
<td>3.28</td>
<td>3.67</td>
<td>3.66</td>
<td>3.71</td>
<td>1.31</td>
<td></td>
<td></td>
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<td>3.51</td>
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<tr>
<td>% Ref</td>
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<td>112</td>
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<td>107</td>
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<td>% Chg</td>
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<tr>
<td>PEF L/sec</td>
<td>5.93</td>
<td>6.32</td>
<td>6.42</td>
<td>5.84</td>
<td>3.90</td>
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<td>6.07</td>
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<td>% Ref</td>
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<td></td>
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<td>% Chg</td>
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<td></td>
<td></td>
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<td>-5</td>
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</tbody>
</table>
Comments:
METHACHOLINE CHALLENGE PERFORMED. BASELINE SPIROMETRY AND VITALS ARE WNL. BREATH SOUNDS CLEAR BILAT, SPO2 ON ROOM AIR IS 99%. PT GIVEN METHACHOLINE IN GRADUALLY INCREASING DOSES PER PROTOCOL. AFTER 2ND DOSE, PTS FEV1 WAS DECREASED BY 50% AND PT REPORTS TIGHTNESS IN HER CHEST. LUNGS ARE DIMINISHED BUT REMAIN CLEAR. PT GIVEN ALBUTEROL AEROSOL AND MONITORED UNTIL SPIROMETRY RETURNS TO BASELINE.
Quality Assurance

• Spirometry – 6 standards associated with error codes (0 or 1)
  – Minimum 3 spirograms recorded (8 maximum attempts)
  – Start of test is acceptable (BEV ≤ 5% of FVC) = 0
  – 6 second exhalation = 0
  – End of test criteria met (plateau) = 0
  – 2 of the 3 have ± 150 ml in FVC and FEV1, ±10% in PEF = 000

• MVV – 2 standards
  – 1 breath/second or total rate 60 to 75 breaths/minute
  – Goal = FEV₁ x 40 (or 35 based on textbook)
Quality Assurance

• Lung Subdivisions (Lung volumes)
  – Uses gas analysis... machine is in good calibration, no leaks
  – Gas reaches acceptable level
    • N2 – 3 breaths < 1.5% (stop after 7 minutes if not at ~ 1.5%
    • He % is constant (plateau at ± 0.02% for 30 seconds)

• Plethysmography
  – With shutter open measure $R_{AW}$. Shutter closes to measure $V_{TG}$ at FRC level
  – Panting at about 60/min (1 Hz) during both open and closed shutter
  – Two recordings should be ±10% in all measured values to be acceptable (TLC, FRC, RV, etc.) If a 3rd or 4th test is needed to get the ±10% agreement, only “keep” the 2 that match
Quality Assurance

• DLCO
  – Inspired volume is > 90% of best FVC
  – Breath hold time 9 – 11 seconds, no leaks
  – Discard first 750 ml before analyzing
    – change this to 500 ml if the FVC is <1.5 L (i.e.children)
  – Collect a 1 liter volume to analyze
  – Tracer gas and CO calibration is good
  – Two tests needed that are within ± 10 % or 3 ml CO
    (using the raw DLCO number)
  – Wait 4 minutes between testing
When interpreting.....

• Review the demographics
  – Age, height, gender, race, weight

• Check the symptoms
  – Cough (dry?), SOB, wheezing, chest tightness
  – Any patterns? Seasonal, occupational?

  ‣ When was the last time they had a SABA? LABA? ICS?

• Look over the history and chief complaint
  – Smoker? Pack yrs? Include pipe, cigar, waterpipe
  – Comorbidities?
Co-morbidities: COPD and asthma (in adults)

- Ischemic heart disease (CAD), hypertension, CHF, pulmonary hypertension, M.I., stroke
- Lung cancer
- Restrictive lung diseases (asbestosis, sarcoidosis)
- Pulmonary embolism
- Pneumonia, CF, bronchiectasis
- DM, obesity, OSA, malnutrition, GERD
- Neuromuscular diseases
  - All of the above can cause SOB, or other respiratory symptoms

- Dementia, Alzheimer's, depression
- Osteoporosis, arthritis, gout, hearing loss, vision loss

All of these co-morbidities can affect pulmonary function testing in cooperation, quality, reproducibility
When interpreting

- Read the comments made by the person coaching the test
  - “C/O chest pain”
  - “Frequent coughing”
  - “Unable to perform test, unable to follow instructions”
- Look at the graphs
- Study the numbers and check against the predicted values
- <80 % predicted or <LLN to define abnormalities
  - LLN: Lower limits of normal
Spirometry

Obstruction
- FEV1/FVC < 70% (or < personal)
  - Loop scooped
  - Long expiratory time

Normal
- All values > 80% predicted
  - FEV1/FVC > 70% (or personal)

Restriction
- No obstruction (and)
  - FVC < 80% predicted

Lung Volumes (Body Box, N2, He)

Obstruction
- A.T. - Increased RV, FRC, RV/TLC
- H. I. - Increased TLC

Normal
- All values > 80% predicted

Restriction
- All values reduced by ~%

DLCO

Obstruction
- DLCO/VA normal - bronchitis
- DLCO/VA low - emphysema

Normal
- DLCO/VA > 80%

Restriction
- DLCO/VA normal - M.O., NMD, pregnancy, resection
  - DLCO/VA low - fibrosis

Reduced
- P.E., anemia
- C.O. poisoning
Case study – Mrs. Barrows

**History**

- The patient is a 73-year-old black woman with a previous history of COPD. She denies cough or sputum production. She states that any activity results in breathlessness. She has a 50 pack-year smoking history but quit 4 years ago.
- She had repeated bouts of pneumonia as a child, but has no other occupational or exposure history. She currently takes Advair and uses albuterol as a rescue inhaler. She has not used either medication this morning.

- 66.5 inches tall, 230 lbs (BMI – 37)
- African-American
- Hb 12.21 g/dl
<table>
<thead>
<tr>
<th>Spirometry</th>
<th>Predicted</th>
<th>Measured Pre-tx</th>
<th>% Predicted</th>
<th>Measured Post-tx</th>
<th>% Predicted</th>
<th>% Change</th>
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</thead>
<tbody>
<tr>
<td>FVC (L)</td>
<td>2.56</td>
<td>1.73</td>
<td>67</td>
<td>2.04</td>
<td>80</td>
<td>18</td>
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<tr>
<td>FEV₁ (L)</td>
<td>1.98</td>
<td>0.65</td>
<td>33</td>
<td>0.84</td>
<td>42</td>
<td>28</td>
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<tr>
<td>FEV₁/FVC (%)</td>
<td>77</td>
<td>38</td>
<td></td>
<td>41</td>
<td></td>
<td>9</td>
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<tr>
<td>FEF₂₅%-₇₅% (L/sec)</td>
<td>1.76</td>
<td>0.18</td>
<td>10</td>
<td>0.33</td>
<td>19</td>
<td>81</td>
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<tr>
<td>FEF₉₀ (L/sec)</td>
<td>5.00</td>
<td>2.87</td>
<td>57</td>
<td>2.80</td>
<td>56</td>
<td>-2</td>
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<tr>
<td>MVV (L/min)</td>
<td>87</td>
<td>24</td>
<td>28</td>
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<tr>
<td>Lung volumes</td>
<td>Predicted</td>
<td>Measured Pre-tx</td>
<td>% Predicted</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>SVC (L)</td>
<td>2.56</td>
<td>2.25</td>
<td>88</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>TLCpl (L)</td>
<td>4.38</td>
<td>5.98</td>
<td>136</td>
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<tr>
<td>RVpl (L)</td>
<td>1.82</td>
<td>3.73</td>
<td>205</td>
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<tr>
<td>VTG (L)</td>
<td>2.60</td>
<td>4.40</td>
<td>169</td>
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<td></td>
<td></td>
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<tr>
<td>RV/TLC (%)</td>
<td>42</td>
<td>62</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Mrs. Barrows

<table>
<thead>
<tr>
<th>Diffusion</th>
<th>Pred</th>
<th>Actual</th>
<th>%Pred</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{DL}_{\text{CO}}$ (ml/min/mm HG)</td>
<td>18.1</td>
<td>8.8</td>
<td>49</td>
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<tr>
<td>$\text{DL}_{\text{CO} \text{cor}}$ (ml/min/mm HG)</td>
<td>18.1</td>
<td>9.3</td>
<td>51</td>
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<tr>
<td>$D_L/V_A$</td>
<td>4.31</td>
<td>2.79</td>
<td>55</td>
</tr>
<tr>
<td>$V_A$ (L)</td>
<td>4.38</td>
<td>3.32</td>
<td>76</td>
</tr>
</tbody>
</table>

Hb 12.21 g/dl
Interpretation – Mrs. Barrows

- Good example of a common pattern of pulmonary pathology associated with COPD.
- Spirometry alone puts her in Moderate COPD category or “C” - “D” (no CAT or mMRC scores)
  - Seen in the FEV$_{1}$ and FEV$_{1}$/ratio.

- MVV – patient reached her goal (FEV$_{1}$ x 40)
Mrs. Barrows

• Lung volumes show air trapping (increased RV and RV/TLC ratio) and hyperinflation (increased TLC). The slow VC is significantly larger than even the post-bronchodilator FVC.

• These findings are suggestive of emphysema

• Patient’s response to inhaled bronchodilator suggests some reversibility of the obstruction (Asthma too?).
Mrs. Barrows

• Her DL\textsubscript{CO} shows a severe reduction in diffusion (DLCO/VA) suggestive of emphysema (e.g., loss of alveolar surface area, destruction of capillaries, and increased diffusion distance from the terminal airways).
### Therapy at Each Stage of COPD

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
</table>
| I: Mild | - FEV₁/FVC < 70%  
- FEV₁ ≥ 80% predicted  
Add: Active reduction of risk factor(s); influenza vaccination |
| II: Moderate | - FEV₁/FVC < 70%  
- 50% ≤ FEV₁ < 80% predicted  
Add: short-acting bronchodilator (when needed) |
| III: Severe | - FEV₁/FVC < 70%  
- 30% ≤ FEV₁ < 50% predicted  
Add: regular treatment with one or more long-acting bronchodilators (when needed); Add: rehabilitation  
Add: inhaled glucocorticosteroids if repeated exacerbations |
| IV: Very Severe | - FEV₁/FVC < 70%  
- FEV₁ < 30% predicted  
or FEV₁ < 50% predicted plus chronic respiratory failure  
Add: long term oxygen if chronic respiratory failure. Consider surgical treatments |

COPD classification

**GOLD Classification of airflow limitation**

**RISK**

- CAT < 10
- CAT > 10

**Symptoms score**
- mMRC 0-1
- mMRC >2

**Breathlessness score**

- 0
- 1
- 2
- 3
- 4

- A
- B
- C
- D

- > 2 (or > 1 leading to hospitalization)
- 1 (not leading to hospitalization)
- 0

(Exacerbation history)
Case report: Mr. Z

• 40 yr old white male c/o SOB with activities.
• Has had problems from childhood with wheeze, SOB
• Also snores and makes loud noises during sleep
• Has been taking DPI fluticasone/salmeterol (250/50) 1 puff BID and albuterol MDI 2 puffs PRN- did not feel that they did much
• Had a sleep study that was read as negative but patient stated that he “couldn’t sleep”.
• Being treated for asthma. We saw him at the Victory clinic on his 5th visit
Mr. Z

- PMH includes obesity, renal stones, deviated septum, HTN (controlled) He is 6’3” tall and 320 lbs. (BMI = 39.9)
- Only hospitalization was in 2000 for a catfish puncture to his hand.
- Family history: Son has asthma, Mother – DM, renal stones. Father has hyperlipidemia
- Occupation: Commercial fisherman
- Married, never smoked, drinks about 3 beers a month and about 3 glasses of tea or coffee a day.
Mr. Z

- 1\textsuperscript{st} visit in July with c/o bilateral swelling in his legs, 30 lb weight gain in 3 months. Some DOE noted. Had some labs drawn
- 2\textsuperscript{nd} visit - August F/U with lab work, c/o lumbar pain – Tx with moist heat and stretching
- 3\textsuperscript{rd} visit Oct. c/o dry cough, sinusitis. More issues with DOE, SOB
- 4\textsuperscript{th} visit 2 weeks later in Oct. – nothing remarkable noted
Mr. Z

- Referred to Pulmonary clinic in Nov. for his 5\textsuperscript{th} visit. Spirometry done with frequent errors, hard to get a good quality recording. Odd phonation noted.
Case: Mr. Z

FVC: 4.89 L (79% predicted)
FEV1: 3.74 L (76% predicted)
FEV1/FVC: 76%

No time to get pre/post... we had class
Rescheduled for further testing
Mr. Z – 2 weeks later and pre/post recorded
(changed set-up in spirometer to record full F/V loop)
Mr. Z

**Patient Information**

- **Name:** Mr. Z
- **ID:** 40
- **Age:** 6 ft 3 in
- **Height:** 310 lbs, BMI 38.5
- **Weight:** MALE
- **Gender:** CAUCASIAN
- **Ethnicity:** NO
- **Smoker:** POSSIBLE
- **Asthma:** POSSIBLE

**Test Information**

- **Test Date/Time:** 11:23 AM
- **Post Time:** 10:54 AM
- **Test Mode:** DIAGNOSTIC
- **Interpretation:** NLHEP
- **Predicted Ref:** NHANES III
- **Value Select:** BEST VALUE
- **Tech ID:** ON
- **BTPS (IN/EX):** 1.11/1.04

**Test Results**

Your FEV1 is 69% Predicted

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pre-Test</th>
<th>Trial1#</th>
<th>Trial2#</th>
<th>Trial3#</th>
<th>Pred</th>
<th>%Pred</th>
<th>Best</th>
<th>Trial1#</th>
<th>Trial2#</th>
<th>Trial3#</th>
<th>Trial2#</th>
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</thead>
<tbody>
<tr>
<td>FVC[L]</td>
<td>4.89*</td>
<td>4.89*</td>
<td>4.53*</td>
<td>4.56*</td>
<td>6.20</td>
<td>79</td>
<td>4.51*</td>
<td>4.51*</td>
<td>4.33*</td>
<td>3.89*</td>
<td>-8%</td>
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<tr>
<td>FEV1[L]</td>
<td>3.40*</td>
<td>3.40*</td>
<td>3.05*</td>
<td>3.00*</td>
<td>4.90</td>
<td>69</td>
<td>3.04*</td>
<td>3.04*</td>
<td>2.62*</td>
<td>2.34*</td>
<td>-11%</td>
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<tr>
<td>FEV1/FVC</td>
<td>0.69*</td>
<td>0.69*</td>
<td>0.67*</td>
<td>0.66*</td>
<td>0.80</td>
<td>87</td>
<td>0.67*</td>
<td>0.67*</td>
<td>0.60*</td>
<td>0.60*</td>
<td>-6%</td>
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</tr>
<tr>
<td>FEF25-75[L/s]</td>
<td>2.66</td>
<td>2.66</td>
<td>2.39*</td>
<td>2.33*</td>
<td>4.48</td>
<td>59</td>
<td>2.30*</td>
<td>2.30*</td>
<td>2.06*</td>
<td>1.66*</td>
<td>-13%</td>
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<tr>
<td>FIVC[L]</td>
<td>4.44*</td>
<td>4.03*</td>
<td>4.41*</td>
<td>4.44*</td>
<td>6.20</td>
<td>72</td>
<td>4.26*</td>
<td>4.26*</td>
<td>3.85*</td>
<td>4.01*</td>
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<tr>
<td>PIF[L/min]</td>
<td>147</td>
<td>147</td>
<td>147</td>
<td>144</td>
<td>-</td>
<td>--</td>
<td>121</td>
<td>121</td>
<td>99</td>
<td>114</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Indicates Below LLN or Significant Post Change

- **Pre-Test:** FEV1 Var=0.35L 10.3%; FVC Var=0.34L 6.9%;
- **Post-Test:** FEV1 Var=0.42L 13.9%; FVC Var=0.18L 4.1%;

**Interpretation:** Mild Obstruction and Low vital Capacity possibly due to restriction

**Session Quality F**

Caution: No Acceptable Maneuvers - Interpret With Care.

**Bottom line = Not asthma... Vocal fold problem? Refer to ENT**
Mrs. Jones

- 51 yr old female - chief complaint: SOB and cough
- Arrived to the ED with cough, chest congestion, fever, chills. Prod cough- thick yellow sputum
- PMH includes CHF, COPD, HTN, ASCVD with stents placed in 2007
- Current medications include carvedilol (Coreg), Albuterol MDI 2 puffs BID, lovenox (Enoxaparin), HCTZ, lisinopril (Zestril)
- No known allergies
- Social history: Divorced, 2 PPD for 30 yrs (60 pk/yr)
- Family history includes Cancer, COPD
- Vitals: BP 145/92 mm Hg, HR 128 beats/min, Resp. 24 breaths/min, Temp 97.8 F. SpO2 on Room air- 88%
Mrs. Jones

• Physical exam
  – General – pleasant 51 year old female, awake and alert, mildly dyspneic, occasional congested cough
  – HEENT: Not remarkable
  – Neck: trachea midline without JVD
  – Chest: Bilat BS equal with scattered wheezing and basilar crackles
  – Heart: Regular S1 and S2. No gallops or murmurs
  – Abdomen: Soft, nontender, nondistended
  – Extremities: no cyanosis, some mild clubbing, no edema
  – Ht 5’3”, Wt 113 lbs (BMI – 20)
Mrs. Jones

- CBC:
  - WBC 14.2 (H) 3.8 – 11.0 k/uL
  - RBC 4.36 3.8 – 5.1 m/uL
  - Hemoglobin 10.1 (L) 11.0 – 16.0 g/dL
  - Hematocrit 33.2 34-47%

- Metabolic panel: Meas. Normal range Units
  - Sodium 131 (L) 135 – 148 mmol/L
  - Potassium 4.9 3.5 – 5.15 mmol/L
  - Chloride 94 (L) 96-112 mmol/L
  - CO2 27 21-34 mmol/L
  - Calcium 9.6 8.0 – 11.0 mg/dL
  - Glucose 132 (H) 74-106 mg/dL
  - BUN 17 7 – 18 mg/dL
  - Creatinine 1.10 0.43-1.13 mg/dL
  - SGOT (AST) 24 15-37 U/L
  - SGPT (ALT) 31 30-65 U/L
  - Alk. Phosphatase 100 40-128 U/L
  - Bilirubin, Total 0.5 0.2-1.4 mg/dL
  - Total Protein 7.2 5 – 9 gm/dL
  - Albumin 3.8 3.5-5.0 g/dL
Sorry - Post SABA results are missing but tracing shows no significant change

**Test Results**

Your FEV1 is 28% Predicted. Your Lung Age is 107

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Best</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Trial 1</th>
<th>Pred</th>
<th>%Pred</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC[L]</td>
<td>2.42*</td>
<td>2.42*</td>
<td>2.34*</td>
<td>2.25*</td>
<td>3.40</td>
<td>71</td>
</tr>
<tr>
<td>FEV1[L]</td>
<td>0.75*</td>
<td>0.72*</td>
<td>0.68*</td>
<td>0.75*</td>
<td>2.69</td>
<td>28</td>
</tr>
<tr>
<td>FEV1/FVC</td>
<td>0.31*</td>
<td>0.30*</td>
<td>0.29*</td>
<td>0.34*</td>
<td>0.80</td>
<td>39</td>
</tr>
<tr>
<td>FEF25-75[L/s]</td>
<td>0.26*</td>
<td>0.26*</td>
<td>0.25*</td>
<td>0.29*</td>
<td>2.66</td>
<td>10</td>
</tr>
<tr>
<td>FET[s]</td>
<td>11.18</td>
<td>11.18</td>
<td>11.17</td>
<td>9.05</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

* Indicates Below LLN or Significant Post Change

Pre-Test

FEV1 Var=0.04L 5.1%; FVC Var=0.08L 3.4%;

Interpretation

Severe Obstruction and Low Vital Capacity possibly due to restriction

Session Quality A
### Therapy at Each Stage of COPD

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
</table>
| I: Mild | - \( \text{FEV}_1/\text{FVC} < 70\% \)  
- \( \text{FEV}_1 \geq 80\% \) predicted |
| II: Moderate | - \( \text{FEV}_1/\text{FVC} < 70\% \)  
- \( 50\% \leq \text{FEV}_1 < 80\% \) predicted |
| III: Severe | - \( \text{FEV}_1/\text{FVC} < 70\% \)  
- \( 30\% \leq \text{FEV}_1 < 50\% \) predicted |
| IV: Very Severe | - \( \text{FEV}_1/\text{FVC} < 70\% \)  
- \( \text{FEV}_1 < 30\% \) predicted  
- or \( \text{FEV}_1 < 50\% \) predicted plus chronic respiratory failure |

**Active reduction of risk factor(s); influenza vaccination**

Add short-acting bronchodilator (when needed)

Add regular treatment with one or more long-acting bronchodilators (when needed); Add rehabilitation

Add inhaled glucocorticosteroids if repeated exacerbations

Add long term oxygen if chronic respiratory failure. Consider surgical treatments

COPD classification

Symptoms score
CAT < 10  CAT > 10

Breathlessness score
mMRC 0-1  mMRC >2

RISK
GOLD Classification of airflow limitation

RISK (Exacerbation history)

0 1 2 3 4

A B C D

> 2 (or > 1 leading to hospitalization)
1 (not leading to hospitalization)
Issues

• Spirometry shows Mrs. Jones has very severe COPD by GOLD guidelines: “D” classification
• Her only pulmonary medication on admission was albuterol MDI, 2 puffs BID
• GOLD recommends vaccinations, SABA, LABA (one or more), pulmonary rehabilitation, ICS if repeated exacerbations (at medium dose), oxygen therapy if in chronic respiratory failure, and consideration for LVRS
Mrs. Jones

• Diagnosis: Classification “D” - Very Severe COPD
  – Oxygen at 2 L/min. Keep SpO$_2$ > 90%
  – Albuterol, 2 mg Q4 w/a and PRN a night
  – Symbicort, 160/4.5 mcg 2 puffs BID (rinse after)
    • Breo Ellipta?
  – Ceftriaxone (Rocephin), 2 g IV daily
  – Prednisone, 80 mg daily for 7 days
  – Nicotine replacement patch, 21 mg/day
  – Bupropion, 150 mg once daily
Mrs. Jones

• Smoking cessation counseling
• Nutritional consult
• Social services to discuss end-of-life issues, patient assistance program for medications, home health aides/sitters. Support for ADLs
• At discharge: Set-up home oxygen, nebulizer, start pulmonary rehabilitation
Mrs. Jones

• Consider metered dose inhaler for LABA, ICS combination (Symbicort, Advair MDI, Dulera)... her inspiratory flow is likely too low to administer a DPI (cannot access Spiriva, Advair diskus, Breo Ellipta)
Comments/Conclusions

• Technologist must be well-trained and should have quality checks performed periodically for competency
• Quality should include calibration checks daily?
• Abnormal spirometry showing obstruction should have pre/post SABA assessment made
• Abnormal spirometry often calls for more testing to evaluate lung volumes and diffusion
Conclusions

• Spirometry provides best diagnostic evidence, clear, objective measurement, basis for tracking changes, guides best practice for treatment

• Spirometry results should not exist in a vacuum – history, symptoms, demographics, current medications, co-morbidities, technologist comments on the test, etc. must be included.

• To get a correct interpretation and to decide on treatment – other PFT tests may be needed (in addition to lab, radiologic tests)