Pulmonary Function Testing 101
Hernan Alvarado Jr. B.S RRT, RPFT
Objectives

- Define Pulmonary Function Testing (PFT’s), and indications
- Review Pre–Testing Calibrations
- Review Spirometry, Lung Volumes, Diffusion Capacity
- Predicted/Normal Values
- Acceptability vs. Reproducibility
- Preliminary Interpretations
- Test your knowledge
- PFT’s 102???
Pulmonary function tests provide measures of airflow, lung volumes, gas exchange, response to bronchodilators, and respiratory muscle function.

Basic pulmonary function tests available in the ambulatory setting include spirometry and pulse oximetry; these tests provide physiologic measures of pulmonary function and can be used to quickly narrow a differential diagnosis and suggest a subsequent strategy of additional testing or therapy.
Pre-Testing Procedures

- Maintenance of equipment
- Daily Calibrations
- Calibrate to ambient temperature, barometric pressure, and humidity
- 3L cal syringe (+/- 3% / 3.5%)
- Consider biologic testing to ensure accuracy
Spirometry is a common office test used to diagnose asthma, chronic obstructive pulmonary disease (COPD) and certain other conditions that affect breathing.

Spirometry may also be used periodically to check how well your lungs are working once you're being treated for a chronic lung condition.

Spirometry measures how much air you can inhale and how much you can exhale. Spirometry also measures how fast you can exhale.
Spirometry Values

- Forced vital capacity (FVC): Maximum amount of air inhaled and exhaled... **FORCEFULLY**
- Forced Expiratory Volume 1 sec (FEV1): Volume of air exhaled at the first second, Gold standard for obstructive disease, help determine responsiveness to bronchodilators, used for trending purposes
- FEV1/FVC Ratio (FEV1%): Ratio of FEV1 in comparison to the FVC
- Forced expiratory flow rate 25–75% (FEF 25–75%): Measures 25–75% of the vital capacity. Considered to be reflective of medium to small airways
Sample Spirometry Tracing
Spirometer of the past
Spirometry Interface
Portable Spirometry
Complete Pulmonary Function System
Lung Volumes

Max Inspiration

IRV

End Inspiration

VC

End Expiration

TV

ERV

Max Expiration

FRC

RV

Lung Volumes and Capacities
MedPrepOnline.com
Helium Dilution Technique

- Helium Dilution: This technique is a closed-circuit system where a spirometer is filled with a mixture of Helium and Oxygen.
- The patient is then asked to breathe in the mixture starting from FRC (Functional Residual Capacity), also known as end expiration.
- Because there is no leak of substances in the system, the amount of He remains constant during the test, and the final concentration of He in the spirometer is measured.
Nitrogen Washout Technique

- Similar to He dilution technique
- Both test incorporate a sample/tracer gas
- Patient breathes a concentration of oxygen until equilibrium is reached
- As seen in He dilution starting levels of nitrogen are known and compared with end levels
- Requires more time for steady state to occur, patient is off oxygen during this technique
Body Plethysmography
AKA Body Box

- No rebreathing of gas mixture is necessary
- Computerized system necessary with pressure transducers to measure changes in pressure
- Glass box allows for constant temperature and pressure. (Boyles Law– Pressure changes reflect and increase or decrease in volumes.
- Measurement recorded as Thoracic Gas Volume (TGV or VTG)
- Also used in measurements of RAW or GAW
Lung Volume Special Considerations

- Gas mixture studies require patients to be off O2 to reach equilibrium.
- Gas mixture studies will tend to show a smaller value in comparison to TGV ("Trapped Gas").
- Body box needs higher end equipment with highly trained practitioners.
- Body box may not be best route when considering, claustrophobia, chest tubes, patient size.
Body Box Communication
Diffusion Capacity

- Diffusion capacity of the lung with carbon monoxide (DLCO): Carbon monoxide (CO) diffusing capacity (DL$_{CO}$) provides an objective measurement of lung function.

- It is defined as the lung's ability to take up an inhaled nonreactive test gas, such as carbon monoxide (CO), which binds to hemoglobin.

- CO will bind to hemoglobin with such a high affinity; virtually all of the CO will reach the alveolar space. This will cause the carbon monoxide to cross the alveolar air–blood barrier, and thus reaching a red cell that will bind to hemoglobin, and will not be removed with the
Sample gas containing CO mixture needed
Patient expires to RV before inspiration of gas mixture to TLC
Percentage of gas mixture is known prior to inspiration
Exhaled sample measured after breath hold time (7–9 secs.)
Difference in values known as amount of diffusion capacity
Special consideration needed for patients on high level of O2 may need prolonged time to “washout”….Plus 4mins between
Predicted Values

- Predicted values based on age, sex, height and race, and weight
- Predicted values may vary from institution to institution
- Predicted based on large study groups
- Examples: Knudson, Miller, Crapo, Nhanes etc.
Acceptability Spirometry

- Free from artifacts: Cough or glottis closure during the first second of exhalation
- Early termination or cutoff
- Variable effort
- Leak
- Obstructed mouthpiece
- Satisfactory exhalation: 6 sec of exhalation and/or a plateau in the volume–time curve
Acceptable Maneuver
Unacceptable Maneuvers
Reproducibility
Interpretation

- **FVC/FEV1**
  - Normal > 80%
  - Mild 70–79%
  - Moderate 55–69%
  - Severe <55%
  - FEV1% (>75%)

- **DLCO**
  - Normal > 75%
  - Mild 60–74%
  - Moderate 40–59%
  - Severe <40%

**KISS METHOD > 80%**
The normal range for lung volumes are 80-120% predicted.
Bronchodilator Response

- Degree to which FEV$_1$ improves with inhaled bronchodilator (MDI vs. HHN)
- Documents **reversible** airflow obstruction
- Significant response if:
  - FEV$_1$ increases by 12% and $>200$ml
- Request if obstructive pattern on spirometry
Airway Reactivity Studies

- Methacholine Challenge Testing
- Exercise Induced Asthma Studies
- Histamine Challenge
- Cold Air Studies

- "How can we induce a decrease in airflow"
University Of Pennsylvania- Airways Biology Initiative  
51 N. 39th St. Mutch-4 fl.  
Philadelphia, PA, 19104

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**Diagnosis:**
- Cough: 
- Wheeze: 
- Yrs Smm: 
- Pks/Day: 
- Yrs Quit: 

**Medications:**

**Pre Test Comments:** Good patient effort & cooperation. The results of this test meet the ATS standards for acceptability and reproducibility.

**Post Test Comments:**

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**----- SPIROMETRY ---**

| FEV1 (L)  | 2.87     | 2.91    | 2.88     | 2.81     | 2.77     | 2.69     | 2.72     | 2.65     | 2.61     | 2.51     | 2.28     |
| FEV1/FVC (%) | 58      | 58      | 58       | 57       | 57       | 55       | 56       | 56       | 56       | 57       | 54       |
| FEF 25-75% (L/sec) | 1.51    | 1.61    | 1.54     | 1.40     | 1.39     | 1.42     | 1.45     | 1.39     | 1.27     | 1.06     | 0.83     |
| FEF Max (L/sec) | 7.83    | 7.74    | 7.80     | 7.70     | 7.22     | 7.08     | 6.98     | 6.63     | 6.62     | 6.34     | 6.24     |
| Name:   |  
| Tech:   |  
| Doctor: |  
| ID:     |  
| Height: |  
| Weight: |  
| BSA:    |  
| Age:    |  
| Sex:    |  
| Date:   | 07/10/2007  
| Room:   |  
| Race:   | Caucasian  

**Graphs:**

1. **Pred** and **Post**
2. **Pre** and **Chlg**
3. **Chlg** and **Post**
Spirometry Patterns

The image shows graphs of flow rate vs. lung volume, illustrating normal, restrictive, and obstructive patterns. The graphs depict how different lung conditions affect the flow rate at various lung volumes. The left graph focuses on the relationship between flow rate and lung volume, while the right graph provides a more detailed comparison across different disease states, including normal, obstructive diseases (e.g., Emphysema, Bronchitis), restrictive diseases (e.g., Chest Wall Disease), and pulmonary fibrosis. The normal flow-volume curve is highlighted, indicating the expected flow rates for a healthy lung.
PFT manifestations for COPD

- Mild, Moderate to Severe airway obstruction. (Decreased FEV1, and or FEV1/FVC)
  - COPD GOLD Standards (Post Bronchodilator)
    - A. Stage 1 Mild – FEV1/FVC < .70, FEV1 > or = 80%
    - B. Stage 2 Moderate – FEV1/FVC < .70, FEV1 = 50% – < 80%
    - C. Stage 3 Severe – FEV1/FVC < .70, FEV1 = 30% – < 50%
    - D. Stage 4 Very Severe – FEV1/FVC < .70, FEV1 = < 30%

- Hyperinflation (Increased TLC, RV, RV/TLC)
PFT manifestations for Asthma

- Reduced airflow (FEV1, PEF, FEF 25–75…)
- Increased airway resistance (RAW)
- Possible hyperinflation (Increased Lung Volumes)
- Normal DLCO
- B2 reversibility?
- Positive methacholine, exercise induced, cold air induced study? (Some consider as Reactive Airway Disease)
Is it Asthma or COPD?

A new cigarette for the tobacco industry’s most loyal customers!

Yeah, they’re gonna kill me and anyone who gets near me, but guess what...

...I don’t give a damn!
University Of Pennsylvania- Airways Biology Initiative  
51 N. 39th St. Mutch-4 fl.  
Philadelphia, PA, 19104

Name: [redacted]  
ID: [redacted]  
BSA: 1.92  
Date: 03/10/2006  
Tech: [redacted]  
Height: 165.00  
Age: 52  
Room:  
Doctor: [redacted]  
Weight: 85.00  
Sex: Female  
Race: <Unspecified>

Diagnosis: RES 19044- study session 1  
Dyspnea:  
Cough:  
Wheeze:  
TbcO Prod: Cigarette  
Yrs Smk: 39.0  
Pks/Day: 1.5  
Yrs Quit:  
Medications:  
Pre Test Comments:  
Post Test Comments: Good effort t/o all testing. Post studies done with 2p Ventolin via spacer. All reported data is valid and reproducible...H.A.

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### Spirometry

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### Lung Volumes

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Good patient effort & cooperation. The results of this test meet the ATS standards for acceptability and reproducibility.
An arterial blood gas (ABG) test measures the acidity (pH) and the levels of oxygen and carbon dioxide in the blood from an artery.

This test is used to check how well your lungs are able to move oxygen into the blood and remove carbon dioxide from the blood.

As blood passes through your lungs, oxygen moves into the blood while carbon dioxide moves out of the blood into the lungs.
Radial Puncture: Easily accessible, disadvantages include pain, agitation, bleeding, and radial artery damage. (Allen’s test used to decrease potential damage to tissue)

Brachial Puncture: Larger vessel allowing for larger target area. Disadvantages include, pain agitation, bleeding, brachial artery damage that can cause decreased circulation to forearm and hand.
Indwelling Catheters: Reliable steady state results, easy access, and consistent blood pressure readout. Disadvantages are infection, bleeding, clotting, and swelling.

Capillary Puncture: Easily accessible, reduces complications, can be useful in pH and PCO2 assessment. Disadvantage is the lack of PO2 assessment.
ANALYZE THE pH

The first step in analyzing ABGs is to look at the pH.

Normal blood pH is 7.4, plus or minus 0.05, forming the range 7.35 to 7.45. If blood pH falls below 7.35 it is acidic. If blood pH rises above 7.45, it is alkalotic.

If it falls into the normal range, label what side of 7.4 it falls on. Lower than 7.4 is normal/acidic, higher than 7.4 is normal/alkalotic.
ABG INTERPRETATION

- Analyze the CO2. The second step is to examine the pCO2. Normal pCO2 levels are 35–45 mmHg. Below 35 is alkalotic, above 45 is acidic.
- Analyze the HCO3 level. A normal HCO3 level is 22–26 mEq/L. If the HCO3 is below 22, the patient is acidotic. If the HCO3 is above 26, the patient is alkalotic.
ABG INTERPRETATION

- Next match either the pCO2 or the HCO3 with the pH to determine the acid-base disorder. For example, if the pH is acidotic, and the CO2 is acidotic, then the acid-base disturbance is being caused by the respiratory system. Therefore, we call it a respiratory acidosis.

- However, if the pH is alkalotic and the HCO3 is alkalotic, the acid-base disturbance is being caused by the metabolic (or renal) system. Therefore, it will be a metabolic alkalosis.
QUESTIONS???