Spirometry 101 for the Primary Care Physician

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A web-based learning module

Target audience:
Primary care physicians and other clinicians
Completion time: 60 min

Disclosures

Barbara P. Yawn, MSc, MD, has disclosed the following relevant financial relationships:

Financial Relationship with a Commercial Interest:
Novartis, BI-Pfizer: COPD screening study
Merck: advisory board adult vaccines
BIPfizer grant: Screening for COPD in family medicine practice
Novartis grant: Rate of exacerbations before and after COPD diagnosis
Merck: Incidence of Herpes Zoster eye complications

Financial Support from a Non-Commercial Source:
AHRQ grants: asthma tools for primary care and RCT, screening for postpartum depression, use of LAMA in black adults with asthma
CDC grant: Herpes Zoster surveillance

Relationship with Tobacco Entity: none
Learning Objectives

- Recognize indications and contra-indications for spirometry.
- Describe the necessary steps and techniques to properly perform spirometry.
- Recognize signs of a poor spirometry tracing.
- Recognize the basic patterns for obstructive, restrictive and normal spirometry results.
- Determine the appropriate therapy for a patient based upon spirometry results coupled with individual history and symptoms.

Spirometry Indications

- Evaluate dyspnea
- Detect pulmonary disease in high risk symptomatic patients
- Monitor effects of therapies
- Evaluate respiratory impairment and operative risk
- Establish baseline lung function
- Provide surveillance for occupational-related lung disease

“Spirometry is to Dyspnea as an EKG is to Chest Pain.” So Why Don’t We Use Spirometry?

Key Parameters in Spirometry

- **FVC** (forced vital capacity): Normal lungs typically empty 80% or more of volume in 6 seconds or less.

- **FEV\(_1\)** (forced expiratory volume in the first second of the forceful exhalation): Normal lungs typically expel 80% of the FVC in 1 second. Reduction in this reading may signify loss in maximum inflation of the lungs, airway obstruction, or respiratory muscle weakness.

- **FEV\(_1\)/FVC**: Core for clinical decision making.

**Spirometry**

**Contraindications**
- Hemoptysis of unknown origin
- Pneumothorax
- Unstable angina or recent myocardial infarction (MI)
- Thoracic, abdominal, or cerebral aneurysms
- Recent eye, abdominal, or thoracic surgery
- History of syncope associated with forced expiration

**Poor quality likely if**
- Pain, stress incontinence or cognitive dysfunction


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**2005 ATS/ERS Standards**

**Position**

- **Position**
  - Sitting is preferable for safety reasons in order to avoid falling due to syncope.
    - Chair should have arms and be without wheels.
  - Obese patients with mid-section distribution will frequently be able to take a deeper breath if tested standing.
  - If test is performed standing, a chair without wheels should be placed behind them.
  - Report should include the position tested.
2005 ATS/ERS Standards
Preparations

Subject preparation

- Activities that should preferably be avoided prior to lung function testing:
  - Smoking within 4 hours of testing
  - Consuming alcohol within 4 hours of testing
  - Performing vigorous exercise within 30 minutes of testing
  - Wearing clothing that substantially restricts full chest and abdominal expansion
  - Eating a large meal within 2 hours of testing

2005 ATS/ERS Standards
3 Phases of the Maneuver

#1 DEEP inhalation
#2 BLAST out
#3 Keep blowing for 6 sec
Use nose clips

Dramatically demonstrate these steps using exaggerated body language (before they try it).
2005 ATS/ERS Standards
Standardization of Spirometry

• **Note**: a *Useable curve*
  - Have a good start
  - Have a satisfactory exhalation
• *While an Acceptable curve should also be*
  - Free from artifacts
• *If results are normal, then it is probably useable*

2005 ATS/ERS Standards
Test Result Selection

• FVC and FEV\textsubscript{1} selected from a minimum of 3 expiratory maneuvers.

  **Largest FVC and the largest FEV\textsubscript{1}** should be used for results after examining the data from all *of the useable curves*, even if they do not come from the same curve.
Jim (Case #1)

- Jim travels extensively as a member of “the Pythons,” a professional soccer team.

- 2 months ago, Jim was seen at an urgent care clinic for chest tightness and cough which he experienced during a soccer match.

- He was told that it might be due to asthma and given an inhaler to use “daily” and one “as needed.”

Additional History from Jim

- He had frequent respiratory infections as a child.
- His mother and younger sister have asthma.
- He used to jog and play in league basketball.
- He has seasonal hay fever symptoms.
- He only smokes “fat” cigarettes occasionally.
- He has no pets in the house.
- He has never been hospitalized.
The Asthma APGAR Test

Jim reported:
- Asthma interrupted usual activities >1 day each week (1 point)
- He had daytime symptoms >3 days a week (1 point)
- He had nighttime symptoms >once a week (1 point)
- He used the albuterol inhaler 1 or 2 times a day and missed his other medications frequently
- He thinks that his asthma is somewhat responsive to his medicines

Total score = 3

Based on this history, do you think Jim has mild, moderate, or severe asthma?


Symptoms to Define Asthma Severity

- Jim’s Asthma APGAR score is 3 out of a total of 6.
- A score of more than 2 points suggests that the patient’s asthma is not optimally controlled.*
- Similar to the Rules of 2.
- Should prompt reassessment of asthma therapy.
- In this case perhaps looking at adherence before stepping up.*

The “Rules of 2” **
>2 symptoms/week
>2 awakenings/month
>2 albuterol refills/yr

*Yawn 2008.
**Baylor HCS.
Further Tests for Jim

What tests would you order to confirm asthma?

a. Peak flow monitoring at home  
b. Treadmill for exercise-induced bronchospasm  
c. Chest x-ray  
d. Spirometry in your office  
e. Lung volumes and DLCO test in a PFT lab  
f. Methacholine challenge test  
g. Total serum IgE level  
h. Sputum eosinophil count
New Spirometers: Portable Office Spirometer

Many Models of Office Spirometers
Normal Trace Showing FEV1 and FVC

FEV₁ = 4L  
FVC = 5L  
FEV₁/FVC = 0.8

Spirometry: Obstructive Disease

FEV₁ = 1.8L  
FVC = 3.2L  
FEV₁/FVC = 0.56
Flow Volume Curve

### Expiratory flow rate
- **L/sec**
- **FVC**
- **Maximum expiratory flow (PEF)**
- **TLC**
- **RV**

### Inspiratory flow rate
- **L/sec**
- **TLC**
- **FVC**
- **RV**

### Volume (L)

Flow Volume Curve Patterns Obstructive and Restrictive

- **Obstructive**
  - Reduced peak flow, scooped out mid-curve

- **Severe obstructive**
  - Steeple pattern, reduced peak flow, rapid fall off

- **Restrictive**
  - Normal shape, normal peak flow, reduced volume
Flow Volume Loops

What is Normal? Criteria for Normal Post-bronchodilator Spirometry

- \( \text{FEV}_1 \): % predicted >80%
- \( \text{FVC} \): % predicted >80%
- \( \text{FEV}_1/\text{FVC} \): >0.7*
  - *However abnormal should take the LLN into account, especially in older adults. (false positives)*
**ATS Standards**

*To be Judged Abnormal*

- Full inhalation at the start of test
- Satisfactory start of exhalation
- No cough or glottal closure during the first second
- No evidence of leak
- No evidence of early termination or cutoff
- No evidence of obstruction of the mouthpiece
- Satisfactory exhalation (at least 6 seconds and/or plateau in the volume-time curve)


**Predicted Normal Values**

Affected by:

- Age
- Height
- Sex
- Ethnic Origin
Getting Ready

- Perform daily spirometer calibration checks – Some of the newer instruments are precalibrated.
- Measure height accurately (without shoes) prior to first test.
  - For patients who cannot stand or who have kyphoscoliosis, measure total arm span.


How to Perform Spirometry

- Explain the test and demonstrate the maneuver.
- Coach for maximal inhalation, then have the patient “blast out” air.
- Encourage blowing out for at least 6 seconds.
- If necessary, instruct the patient how to correct any problems.
- Obtain 3 good results, with the best 2 matching closely.
Reproducibility Goals

- Closely matching means:
  - Match FEV₁s within 0.15 liters
  - Match FVCs within 0.15 liters

It may take up to 8 efforts to meet the goal.

What Can Go Wrong?

- Poor inhalation efforts
- Lack of a blast effort
- Short maneuvers
- Inaccurate spirometer
- Wrong height, age, or race
- Incorrect reference equation
- All of the above

Goal: Minimize misclassification
Jim’s Spirometry Results

The green convex curve confirms airway obstruction.

<table>
<thead>
<tr>
<th>Results</th>
<th>% Pred</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV₁</td>
<td>1.2 L</td>
</tr>
<tr>
<td>FVC</td>
<td>2.9 L</td>
</tr>
<tr>
<td>FEV₁/FVC</td>
<td></td>
</tr>
</tbody>
</table>

- The low ratio confirms obstruction.
- An FEV₁ <60% predicted suggests severe, poorly controlled asthma.

Spirometry Helps to Classify Asthma Severity

The severity of airway obstruction is often worse than many patients (or parents) recognize.

According to GINA guidelines, Jim has severe, persistent asthma (despite relatively mild complaints).
Why Use the Asthma APGAR? Patients Underestimate Severity and Overestimate Control

Prospective study of 596 patients with asthma, ages 2-54, seen in ED. Only 1 in 4 patients treated for asthma in the ED considered their asthma poorly controlled despite frequent asthma symptoms and healthcare utilization.

Camargo et al. [abstract] Chest. 2001;120(suppl):171S.

Patient Perception of Symptom Severity

- Indicated with airway obstruction
- Helps differentiate between reversible (asthma) and irreversible disease (COPD)
- Administer 2-4 puffs of albuterol with a metered-dose inhaler and spacer
  - Wait 5 to 15 minutes for its effect

The Bronchodilator (BD) Test
2005 ATS/ERS Standards
Dose of Bronchodilator for Reversibility Testing

- Albuterol – each 4 doses x 100 mcg, 30 seconds apart, or
- Ipratropium bromide – 4 x 40 mcg, 30 seconds apart

Cited references do not use these doses, including the author’s own paper.
These are double the FDA approved dose.
In discussion: “...should be administered in the same dose...as used in clinical practice...”

Jim’s Post-bronchodilator Test:
Determination of Reversibility

A large increase in expiratory flows (blue curve) and a higher FEV1 confirms asthma.

The lack of a BD response does not rule out asthma in patients who are asymptomatic on the day of the test.

<table>
<thead>
<tr>
<th></th>
<th>Pre-BD</th>
<th>% Pred</th>
<th>Post-BD</th>
<th>% Pred</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC</td>
<td>2.9 L</td>
<td>57%</td>
<td>4.7 L</td>
<td>92%</td>
</tr>
<tr>
<td>FEV₁</td>
<td>1.2 L</td>
<td>28%</td>
<td>2.3 L</td>
<td>53%</td>
</tr>
<tr>
<td>FEV₁/FVC</td>
<td>41%</td>
<td></td>
<td>49%</td>
<td></td>
</tr>
</tbody>
</table>

>12% and >200cc response is clinically significant
Algorithm for Interpreting Spirometry Results

Is FVC low?
- Yes: Obstructive defect
  - Is FEV₁/FVC ratio low?
    - Yes: Further testing
    - No: Restrictive defect
  - No: Pure obstruction
    - Reversible with use of beta agonist?
      - Yes: Further testing
      - No: Mixed obstructive/restrictive defect or hyperinflation
- No: Acceptable spirogram

Available at: ttp://www.nlhep.org/resources/SpirometryMadeSimple.htm.

2005 ATS/ERS Pulmonary Function Interpretation Algorithm

For identification of obstruction

Use LLN for FEV₁/FVC

NOT a fixed ratio of 0.70

Roberts SD, Farber MO, Knox KS, Phillips GS, Bhatt NY, Mastronarde JG, Wood KL.
FEV₁/FVC Ratio of 70% Misclassifies Patients With Obstruction at the Extremes of Age.
Chest 2006;130;200-206.

Also see Falling Ratio Working Group at:
http://www.spirxpert.com/controversies/controversy.html
Withholding Medications

• Before performing spirometry, try to withhold:
  – Short acting β2-agonists for 6 hours
  – Long acting β2-agonists for 12 hours
  – Ipratropium for 6 hours
  – Tiotropium for 24 hours

Optimally, subjects should avoid caffeine and cigarette smoking for 30 minutes before performing spirometry

Medical Treatment Plan for Jim

 – Asthma controller medication explained and daily use stressed—worked through reasons for non-adherence
   (medium dose ICS and LABA—Step 3 or 4)
 – Continue asthma rescue inhaler
 – Prevent EIB: albuterol before exercise
 – Return to office within 1-3 months for treatment re-evaluation
Another Benefit of Spirometry: Objective Measurement of Treatment Effectiveness

Not all asthma and COPD medications work as advertised for every patient.

- 20% respond to LTA
- 80% respond to ICS
- Some get worse with LABAs

Jim Returns 3 Months Later

- Spirometry: FEV\textsubscript{1} = 95% predicted
- Feeling well without exercise limitation
- Asthma APGAR score = 1 = good asthma control
  - Rule of 2: all negative
- My recommendations:
  - Consider a step-down in therapy
  - Follow-up every 3 to 6 months—before “seasons”
  - Allergen skin testing

An FEV\textsubscript{1} improvement of more than 20% is substantial.
Summary of Jim’s Case

- Spirometry confirmed the diagnosis of asthma.
- His Asthma APGAR score, or "Rules of 2" score, and his airway obstruction verified his need for improved asthma controller therapy.
- Repeat spirometry provided an objective evidence that he responded well to the aggressive therapy.
- Both symptoms and spirometry results are helpful to guide the need for step-up or step-down of asthma controller therapy.

FORCED VITAL CAPACITY (FVC)
Severe Obstruction
FORCED VITAL CAPACITY (FVC)
Severe Restriction

Non-Reproducible Test

Three times FVC within 5% or 0.2 litre (200 ml)

Unacceptable Trace - Poor Effort

- Variable expiratory effort
- Inadequate sustaining of effort
- May be accompanied by a slow start

“Quit Too Soon”

- Patient starts out fine, but appears to quit too soon
- The test needs to be repeated

“Hesitating Start”

• A patient who hesitates during the start of the test produces a noticeable “zig-zag” in the curve
• It lacks a rapid climb to peak flow
• The test needs to be repeated


“Cough”

Unacceptable Trace – Extra Breath

Fred (Case #2)

- Six months ago, Fred accidentally set the front seat of his patrol car on fire. He inhaled fumes from the burning plastic as he attempted to extinguish the fire.
- His wife insisted that he see you because of his irritating persistent cough.
- He denies smoking, heartburn or allergies, and takes no medications.
- His exam: BP 152/92, yellow teeth, halitosis, mild obesity, normal exam otherwise.

You perform spirometry
Fred’s Spirometry Results

This report is from a spirometer connected to a PC.

A bronchodilator was not given.

Your Assessment of Fred

- His spirometry results were not as reproducible as you would like but they are normal.
- His chronic cough is probably due to smoking. It may have been aggravated by smoke inhalation at work, and possibly GERD.
- During his exam, he admits smoking ever since his military service in the Gulf War.
- Normal spirometry rules out COPD, but not asthma.
- His risk for other smoking-related diseases remains high.
**Estimated Growth & Decline of Lung Function**

Fred’s “lung age” is 44 y/o (real age is 31) motivation to quit smoking?

**Your Treatment Plan for Fred**

- Diagnosis of chronic cough
- Offered help with smoking cessation
  - Bupropion (25% success rate)
  - Varenicline (50% success rate)
- Considered an H2 blocker trial but no history of reflux symptoms
- Scheduled a return visit in one month to check symptoms and smoking status
Avoid Interpretation Pitfalls

**Common Interpretation Errors Among Family Physicians (N = 12) New to Interpreting Spirometry**

- Interpreting a normal result as an obstructive pattern
- Interpreting a poor effort as a restrictive pattern
- Diagnosing COPD in the absence of an FEV₁/FVC ratio <70%


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2005 ATS/ERS Pulmonary Function Interpretation

**FEF25-75**

- Not specific for “small airways disease”
- “Highly variable” i.e. not repeatable
- Does not indicate bronchodilator response
  - May decrease despite an increase in FEV₁ if FVC increases to a greater degree
Pitfalls in Interpretation of Spirometry in COPD

- A significant acute bronchodilator response to short-acting bronchodilator does not rule out COPD.
- Patients with an “irreversible” FEV\(_1\) acute bronchodilator response may still have a beneficial lung volume response.
- Short-term FEV\(_1\) response may underestimate long-term response.
- Lack of response to one class of drug does not imply non-responsiveness to another class.
- Other outcome measures may not correlate with changes in FEV\(_1\) and should be considered in assessing response to therapy.

Benefits of Spirometry: Conclusions

- Spirometry is a powerful diagnostic tool
  - It provides objective documentation of lung function
- Spirometry is accurate and easy to use
  - Modern spirometers automatically report test quality
  - Reimbursement easily covers the costs
- Spirometry helps manage and monitor treatment
  - The BD test shows short-term reversibility of asthma
  - Follow treatment responses using the FEV\(_1\)