Pulmonary Function Tests for Pulmonary Specialists

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A web-based learning module

Target audience:
Pulmonary specialists
Completion time: 60 min

Disclosures

Paul D. Scanlon, MD, has disclosed the following relevant financial relationships:
Financial Relationship with a Commercial Interest:
Grants from Glaxo, Novartis, Altana, Boehringer Ingelheim
Financial Support from a Non-Commercial Source:
NHLBI and Department of Energy
Relationship with Tobacco Entity: none

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
BioPfizer 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 post partem depression, use of LAMA in black adults with asthma
CDC grant: Herpes Zoster surveillance
Relationship with Tobacco Entity: none

Paul L. Enright, MD, has disclosed the following relevant financial relationships:
Financial Relationship with a Commercial Interest:
Consultant or Advisory Board:
Pfizer Chantix
Gilead 1PF
Expert Testimony:
Setter Legal Asbestos
Relationship with Tobacco Entity: none
Objectives

- Appropriately screen patients for risk of asthma and COPD.
- Accurately interpret spirometry results.
- Identify characteristics that differentiate COPD and asthma.
- Classify spirometric abnormalities from mild to very severe.
- Prescribe an appropriate treatment regimen for patients with COPD and asthma.
- Enhance patient compliance to treatment regimens via effective physician/patient communication skills.
- Effectively communicate spirometry findings to primary care physicians (for pulmonologists).

Key Learning Concepts

1. Order spirometry to detect or confirm COPD.
2. Normal spirometry rules out COPD, but not asthma.
3. PFTs assist differential diagnosis in patients with a chronic cough or new-onset dyspnea (COPD, asthma, IPF, PAH, vs deconditioning).
4. Moderate to severe obstruction in an adult smoker: very high probability of COPD.

5. With dyspnea, a low FVC is non-specific, common with obesity; check DLCO and CXR.


7. Spirometry and DLCO confirm treatment responses in asthma, COPD, and IPF.

**Key Learning Concepts**

**Sam** is a 53 y/o house painter. Has smoked for 25 years. Chronic cough and phlegm. Complains of 3 months of DOE.

**Which 3 of the following tests initially will be most helpful to diagnose the cause of his dyspnea?**

1. Chest X-ray  
2. Body plethysmography  
3. Cardiopulmonary exercise testing  
4. Pre- and post-BD spirometry  
5. DLCO  
6. Maximal respiratory pressures
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2. Body plethysmography
3. Cardiopulmonary exercise testing
4. Pre- and post-BD spirometry
5. DLCO
6. Maximal respiratory pressures

His chest x-ray is normal.

His spirometry results:

- FEV1 = 2.3 liters (85% predicted)
- FVC = 2.6 liters (76% predicted)
- FEV1/FVC = 0.88

**Which of the following statements is true?**

(check all of the true statements)

1. The low FVC could be due to obesity.
2. He may have mild asthma.
3. He has airway obstruction.
4. COPD is ruled out.
5. The quality of the spirometry test is poor.
6. He may have pulmonary hypertension.
1. The low FVC could be due to obesity. **True**; abdominal obesity can cause a mildly low FVC.

2. He may have mild asthma. **True**; although spirometry does not show airway obstruction (FEV1/FVC is normal and his flow-volume curve shows no curvilinearity), people with asthma often have normal spirometry (or a mildly low FVC due to abdominal obesity, as in this case).

3. He has airway obstruction. **False**; FEV1/FVC is normal and his flow-volume curve shows no curvilinearity.

4. COPD is ruled out. **True**; His FEV1/FVC is normal.

5. The quality of the spirometry test is poor. **False**; All curves are acceptable and repeatable.

6. He may have pulmonary artery hypertension. **True**; spirometry is not helpful for detecting PAH.

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**Which of the following statements is true?**

- Low FVC or FEV1
- Normal FEV1/FVC
- Normal TLC box
- Also called “spirometric restriction”
- Normal TLC, so not true restriction
- First described by Robert Hyatt, MD
- 9% prevalence in PFT lab patients
Possible Clinical Correlates for the Non-Specific Pattern

- Poor inspiratory efforts during spirometry
- Short expiratory efforts (lack of VT plateau)
- Obesity or weak expiratory muscles
- Air trapping (increased RV) due to obstruction
- Asthma or COPD?

Which Two PFTs, if Normal, Would Greatly Reduce the Likelihood of an Interstitial Lung Disease Causing His Dyspnea?

1. Maximal respiratory pressures
2. Lung volumes by body box
3. DLCO
4. MVV
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4. MVV

Normal Lung Volumes Rule Out Restrictive Disorders
DLCO Helps to Differentiate Between Major Lung Disease Categories
**Thomas** is a 52 year-old policeman with a history of chest tightness and dyspnea when jogging in cold weather. He has lifelong nasal allergies and smoked a pack-a-day since a teenager, until quitting 4 years ago. He takes loratidine and multivitamins daily. His nurse practitioner used a pocket spirometer to measure his FEV1 as only 35% predicted and a lung age of 95.

**What should you order next?**
1. Tiotropium to treat COPD
2. Allergen skin testing
3. Chest CT to screen for lung cancer
4. Repeat spirometry, pre- & post-BD
What is Your Diagnosis?

1. Asthma; Probably. His history of intermittent chest tightness with dyspnea during exercise makes the pre-test probability of asthma intermediate to high. Moderate airway obstruction with a very large improvement following albuterol makes asthma likely. Considering his history of smoking, these symptoms could also be due to angina, so you should consider coronary artery disease.

2. COPD alone; Probably not. He has persistent airway obstruction post-BD. It is uncommon for people with COPD alone to have a very large BD response.

3. Asthma and COPD; Possibly. It is uncommon for people with COPD alone to have a very large BD response, but the disorders can co-exist. Confirmatory tests are available for both conditions.

4. Vocal cord dysfunction (VCD); Probably not. The expiratory flow-volume curve indicates an intra-thoracic process. The normal inspiratory flow-volume curve argues against an extra-thoracic process. Patients with VCD typically have limitation of forced inspiratory flows. Laryngoscopy during exercise is available to definitively evaluate vocal cord dysfunction.
What Tests Would Help Confirm Either Asthma or COPD?

1. Exhaled nitric oxide  
   Yes, a high eNO indicates eosinophilic airway inflammation due to asthma.

2. Total blood eosinophil count  
   No, eosinophils are also elevated with allergic rhinitis (which he has had since childhood).

3. Static lung volumes  
   No, hyperinflation of lung volumes may result from airway obstruction in either asthma or COPD.

4. Diffusing capacity  
   Yes, a normal DLCO makes asthma more likely, but there are some cases of COPD (indicated by the presence of emphysema on CT) with normal DLCO. DLCO is often increased in asthma.

5. Chest CT  
   Yes, the presence of emphysema confirms a diagnosis of COPD, even if DLCO is normal. There are some cases of centrilobular emphysema with normal spirometry and occasionally normal DLCO as well.
Tom is a 46 year old race car driver referred from his primary care doctor for dyspnea on exertion, slowly increasing during the past year or two. Peak flow was 480 LPM (70% predicted), interpreted as possible obstruction. He has a productive morning cough, but no hemoptysis. No allergies and no medications. Smoking since age 15. He can walk up 6 flights of stairs without shortness of breath. BMI=29. SpO2=95%. Lungs clear; normal chest x-ray.

Your PA performed spirometry ten minutes ago. Please guess his post-BD FEV1:

1. 30% predicted
2. 50% predicted
3. 75% predicted
4. 100% predicted
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2005 ATS/ERS Spirometry Standard Acceptability Criteria

1. Satisfactory start
2. No cough in 1st second
3. Satisfactory end-of-test
4. No Valsalva maneuver (glottis closure)
5. No leak
6. No obstructed mouthpiece
7. No extra breath
What is Wrong With the Quality of These FVC Maneuvers?

1. Poor "blast out" efforts.
   No; all have sharp peak flows. None have hesitating or slow starts.

2. Quit too soon.
   Yes, your PA allowed him to quit after 6-8 seconds of exhalation for all maneuvers. The volume-time curves did not plateau, thus his FVC was under-estimated for all maneuvers. However, it was near 100% predicted (blue x) for one of the post-BD maneuvers (green line), so the measured vital capacity was normal.

3. Poor FVC repeatability.
   No; the FVCs match closely. The ATS goal is for the highest two FVCs to match within 0.20 liters.

4. Submaximal inspiratory efforts.
   No; the forced inspiratory flows have a normal shape and the FIVCs match closely.
Interpreting BD Responses

- >12% and >0.2 liters FEV1
- Beyond measurement noise (+/-10%)
- Don’t use FEF25-75%
- Don’t use sGaw, FOT, MVV, etc.
- Consider reduced hyperinflation (increase in FVC)
- Is the change also clinically important?
BD Change is Often Not Helpful

- A lack of BD response does not rule out asthma nor confirm COPD.
- A lack of BD response does not predict a lack of response to LABAs or ICS therapy.
- A borderline to mild improvement frequently occurs in smokers with COPD.

Enid is a 76 y/o history professor, referred for persistent dyspnea despite maximal asthma therapy. She has a 20 pack-year smoking history and BMI 37.2

FEV1 = 2.2 liters pre-BD (85% predicted)
FVC = 2.7 liters (79% predicted)
FEV1/FVC = 0.81

What two diagnoses are most likely?
1. COPD
2. Asthma
3. Interstitial Lung Disease
4. Pulmonary hypertension
5. Obesity with deconditioning
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**What two diagnoses are most likely?**

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**What Test(s) Would Help to Distinguish Between These Conditions?**

- Interstitial lung disease
- Obesity with deconditioning
DLCO Helps to Differentiate Between Major Lung Disease Categories

1. **FEV₁/VC ≥ LLN**
   - Yes → VC ≥ LLN
     - Yes → Normal
     - No → TLC ≥ LLN
       - Yes → Normal
       - No → Restriction
2. **VC ≥ LLN**
   - Yes → TLC ≥ LLN
     - Yes → Normal
     - No → Obstruction
       - Yes → Normal
       - No → Mixed defect
3. **TLC ≥ LLN**
   - Yes → DLCO ≥ LLN
     - Yes → Normal
     - No → PV disorders
   - No → CW and NM disorders
   - No → ILD Pneumonitis
   - No → Asthma CB
   - No → Emphysema
Interpretation Algorithm

**FEV1/VC is generally ≤ FEV1/FVC**

- FEV1/VC is not provided by NHANES reference equations or any US standard, overestimates obstruction
- VC methods not agreed upon (IVC vs. EVC vs. largest value from any maneuver in spiro, lung vols, or DLCO)

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**52 y/o F  Mild Dyspnea with Exertion, Wheezing, Never Smoker**

Ht : 167.9 Wt: 103.4 BMI: 36.7

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<th>Parameter</th>
<th>Value</th>
<th>Comment</th>
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<td>RV</td>
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<td>FEV1/FVC</td>
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<td>SRaw</td>
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<tr>
<td>DLCO</td>
<td>25</td>
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<td>95%→96%</td>
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- Nonspecific pattern with increased airways resistance and bronchodilator responsiveness
- Note that RV is ALWAYS increased in nonspecific pattern and does not necessarily indicate airway closure
52 y/o F  Mild Dyspnea with Exertion, Wheezing, Never Smoker
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"Abnormal.  FEV₁ and FVC are mildly [moderately] reduced in a nonspecific pattern with a normal TLC and FEV₁/FVC ratio.  Obesity may contribute to this pattern.  The increased airway resistance and the response to bronchodilator indicate an element of reversible obstruction as well.  DLCO and oximetry are normal."

Controversies Over ATS 2005 Interpretation Algorithms
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:

**Interpretation Algorithm**

“PV Disorders” Includes:
- Pulmonary parenchymal disorders including early ILD & emphysema
- Anemia
- Pulmonary vascular disorders

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<Figure 2: Simplified algorithm that may be used to assess lung function>
What is “Obstruction” with nl FEV1/VC?

- “Nonspecific pattern”
- Commonly seen in asthma & COPD but also in obesity, weakness
- >9% of all PFT’s at Mayo Clinic
- 50% have normal Raw*
- Long term study in progress

Impact of Asthma

Impairment/Severity Stratifications
Adapted from 1986 ATS Disability Standard

Obstruction (80/60/40)

FEV1/FVC < LLN* AND:

- Borderline – FEV1 ≥ LLN*
- Mild – FEV1 60% - LLN*
- Moderate – FEV1 41-59%
- Severe FEV1 31* - 40%
- Very Severe ≤30%*

Restriction (80/60/50)

FEV1/FVC ≥ LLN* AND TLC < LLN AND:

- Mild – FVC 60% - LLN*
- Moderate - 51 to 59%
- Severe ≤50%
- Very Severe (≤35%?)*

* modifications
2005 Severity Classification - Spirometry

Table 4. Severity of any spirometric abnormality based on the FEV₁ as % of predicted.

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<td>35-49</td>
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<tr>
<td>VERY SEVERE</td>
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"The number of categories and the exact cut-points are arbitrary."

Enright: Caution re shifting of disease severity, false positives, excess therapy, potential conflict of interest in clinical practice guidelines


Impairment/Severity Stratifications of 1986

Obstruction (80/60/40)
FEV₁/FVC < LLN* AND:
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VS Severity Stratifications of 2005

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Severity Classification - DLCO

Table 8. Degree of severity of decrease in DLCO.

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<th>DEGREE OF SEVERITY</th>
<th>DLCO % predicted</th>
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<tbody>
<tr>
<td>MILD</td>
<td>&gt; 60% and &lt; LLN</td>
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<td>MODERATE</td>
<td>40-60%</td>
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No change compared with 1986

2005 ATS/ERS Standards
Dose of Bronchodilator

Reversibility Testing

- Albuterol - 4 doses x 100 mcg each, 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...”
2005 ATS/ERS Pulmonary Function Interpretation

- FEF25-75
- is not specific for “small airways disease”
- is “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]

2005 ATS/ERS Pulmonary Function Interpretation – Comment on Quality

- Comment on Quality, e.g.:
  "The patient was unable to perform acceptable and repeatable maneuvers, so reported values may underestimate true lung function."
- I do not comment on quality UNLESS it is below par. Be SUCCINCT.
2005 ATS/ERS Pulmonary Function
Omitted Definitions

- **Hyperinflation** – TLC greater than upper limit of normal (ULN) if defined, or 125% predicted if not

- **Air Trapping** – RV greater than ULN. Includes, but does not always indicate “airway closure” (e.g. in chest wall limitation)

**Complex Disorders**

There is no discussion of complex disorders other than “mixed”. For example, obstructive disorders or interstitial disorders in combination with chest wall limitation due to obesity, effusion, kyphosis or scoliosis, complex neuromuscular disorders, etc.
Recommendation for Mixed Disorders

- Grade restriction based on TLC
- Grade overall impairment based on FEV1
- Severity of obstruction is indeterminate

57 y/o M with Sarcoidosis, Severe Dyspnea, Cough & Wheeze
Ht (Arm Span): 167.7   Wt: 76.0

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- Severe mixed abnormality, mild restriction, super-imposed obstruction, minimal bronchodilator response
- Classic cause of mixed pattern
57 y/o M with Sarcoidosis, Severe Dyspnea, Cough & Wheeze
Ht (Arm Span): 167.7 Wt: 76.0 BMI 27.0

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"Abnormal. Severe mixed obstructive plus restrictive disorder. The mild reduction in TLC indicates a restrictive process. The disproportionate reduction in FEV₁, low FEV₁/FVC ratio and the shape of the flow volume curve indicate superimposed obstruction. There is little response to bronchodilator. The moderate reduction in DLCO indicates a parenchymal or vascular disorder."

What Causes a Disproportionate Reduction in FVC vs. TLC (↑RV)?

All of the following except:

A. Neuromuscular weakness
B. Upper airway obstruction
C. Chest wall limitation (e.g. obesity, scoliosis)
D. Superimposed obstruction
E. Poor performance
What Causes a Disproportionate Reduction in FVC vs. TLC (↑RV)?

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Complex Restrictive Disorders

TLC or FVC for Grading Severity?

- The combination of TWO restrictive processes, such as ILD plus weakness, can result in disproportionate reduction in FVC vs. TLC.
- The important issue is not whether to grade restriction based on TLC vs. FVC, but rather, to recognize complexity.
- Recommendation: The primary restrictive process can be graded based on TLC. Overall impairment is best graded with FVC.
REPEAT: What Causes a Disproportionate Reduction in FVC vs. TLC (↑RV)?

All of the following:

A. Neuromuscular weakness
B. Chest wall limitation (e.g. obesity, scoliosis)
C. Superimposed obstruction
D. Poor performance

Note that all will result in increased RV, not necessarily due to “air trapping”.

Indications for Other Tests?

The PF Standards provide no guidance on indications for or use of supplementary PF tests: blood gases, oximetry, MVV, maximal respiratory pressures, airway resistance, eNO, methacholine challenge, cardiopulmonary exercise, ventilatory drive, lung compliance, etc.
Obesity Causes Low DLCO

A. True
B. False

Answer depends on whether your reference equation is based on BSA/BMI. If so, predicted DLCO may be artificially increased and appear to indicate reduced DLCO in obesity.
Indications for FIVC

The following are appropriate indications for measurement of FIVC except:

A. MVV reduced out of proportion to FEV1
B. Patient referred from ENT with known or suspected upper airway pathology
C. Routine testing
D. Goiter
E. Stridor
When is Airway Resistance Useful?

A. Routine testing for patients with known obstruction
B. As part of methacholine challenge
C. For further evaluation of the “nonspecific” pattern
D. For patients with suspected upper airway obstruction
Summary – ATS/ERS 2005 PFT Standards

- Needed update of technical specifications
- Reinforcement of importance of QC program
- Relatively minor changes in technical specifications for spirometry, DLCO
- NEW Lung volumes standard
- Major and controversial changes in interpretation standard

Impairment/Severity Stratifications

Obstruction (80/60/40)
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- Mild – FVC 60% - LLN*
- Moderate - 51 to 59%
- Severe ≤ 50%
- Very Severe (≤35%?)*

<table>
<thead>
<tr>
<th>DEGREE OF SEVERITY</th>
<th>FEV1, % predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>MILD</td>
<td>&gt;70%</td>
</tr>
<tr>
<td>MODERATE</td>
<td>60-69</td>
</tr>
<tr>
<td>MODERATELY SEVERE</td>
<td>50-59</td>
</tr>
<tr>
<td>SEVERE</td>
<td>35-49</td>
</tr>
<tr>
<td>VERY SEVERE</td>
<td>&lt;35</td>
</tr>
</tbody>
</table>

Table 4. Severity of any spirometric abnormality based on the FEV1 as % of predicted.
Coordinating Care Between Physicians

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When it Requires a Village—

Referrals you receive should be explicit
- What is the reason for the referral—ask that this be very specific
  • Help with differential diagnosis
  • Help with complex management of ????
  • Confusing spirometry and clinical history
  • Help convincing patient that COPD can be treated
  • Help with oxygen evaluation and management
  • Help with preventing frequent exacerbations
  • ETC
Make Sure You Know What Has Happened to Date

Ask for a short summary of clinical and test results
- Duration of respiratory issues
- Imaging results
- Copy of spirometry if done
- List of all medications and all chronic conditions
- Important notes regarding issue such as smoking, adherence failures

Who Wanted the Referral?

Who initiated request for referral?
- Patient
- Quality indicators
- Physician
- Patient’s family
- Other
During the Visit

- If the referring physician has done something well—praise them in the presence of the patient and family.

- If the referring physician has not done well, keep it to yourself and include comments and suggestion in the return letter to that physician.

Do What Was Asked or Explain Why You Did Not

- If the referring physician requested a specific evaluation be done—do it unless it is not useful or dangerous and very expensive.

- Do not redo tests with recent results without a clear explanation of why. Saying the referring physician’s equipment is outdated or not read by your staff who are more expert should be stated with humility—NOT arrogance, especially if you would like future referrals.
Send Back a Prompt Report of the Visit

- Letters or secure emails should be received by the referring physician within 3 to 7 days after the visit.
- Please answer any direct questions.
- Summarize your findings.
- Clearly outline the treatment you recommend in a list.
- Report why you changed any medications.

Who is to Continue Care

Make it very clear you are sending the patient back to the care of the referring physician

- Unless you were asked to take over care
- Additional appointments are needed to complete the consultation
- The patient does not want to return to the referring physician
When do You Want to See the Patient Next?

- Report next appointments and reasons for those visits
- Report what will be done at that visit and any thing that should be done before the next visit to manage the patients asthma or COPD
- Provide education when possible
  - “I find annual spirometry is helpful to determine the rapidity of decline and to give me an objective measure to compare to the patient’s reported symptoms.”

The Golden Consult

- You receive what you want and need.
- You give what you would want to have to care for that patient.
- You come away from either referral or consultation summary letter feeling like you are more comfortable or competent than you were before.