A GUIDE TO SPIROMETRY

for

PRIMARY CARE PHYSICIANS

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ABOUT THE AUTHOR:

Dr. Josiah Lowry is a Family Physician, currently in full-time practice in Orillia, Ontario. His practice scope includes both hospital and office practice, regular Emergency shifts, and Obstetrics. He is a Certificant of the College of Family Physicians of Canada and was honoured as a Fellow of the College of Family Physicians of Canada in May, 1996.

He has done post graduate work in respirology at the Firestone Chest and Allergy Unit in Hamilton, Ontario prior to starting the COLD Rehabilitation Program for chronic lung disease patients at the Orillia Soldiers Memorial Hospital in 1985. Dr. Lowry served as Medical Advisor for the program from 1985 to 1994.

Dr. Lowry was Medical Advisor for the Lung Association, Georgian Bay Region from 1982-1990. He developed the Asthma Education Card used throughout the school system in Simcoe County to help students and teachers better understand Asthma medications and emergency treatments. In 1986, he helped produce the very successful continuing education movie for physicians entitled “Coping With COPD” sponsored by Boehringer Ingelheim.

He has done research in Orillia on the management of Acute Asthma in the Emergency Department and developed a protocol that has resulted in fewer visits to the Emergency Room and fewer hospitalizations.

As a community preceptor with the McMaster University Department of Family Medicine from 1994-1997, he has taught Spirometry to Family Practice Residents. Over the past year and a half he has taught the CFPC accredited CME program “COPD and Adult Asthma: Guide to Assessment and Management” to many problem-based small groups of Family Physicians.

This broad-based experience has lead to the recognition of the need for a practical and concise guide for Family Physicians to interpret Spirometry. Boehringer Ingelheim has enthusiastically supported this project in the hope that it would lead to a more rational treatment of lung diseases in primary care.

He would like to acknowledge the generous support and guidance he received from Bill Frampton, RT, head of the Cardiorespiratory Department, Orillia Soldiers Memorial Hospital, Dr.Brian McGugan, Family Physician, Orillia, Dr. Tony D’Urzo, Family Physician, Toronto, and Dr.David Alexander, Respirologist, Orillia, in preparing this document. Their practical advice was invaluable.

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INTRODUCTION:
THE SCOPE OF THE PROBLEM

As a Family Physician treating Hypertension, you wouldn't consider prescribing medication without taking the patient's blood pressure. As an Emergency Physician you wouldn't treat Chest pain without doing an EKG. Yet every day we see Family Physicians treating Asthma and COPD without doing Spirometry. Without Spirometry you lack an objective measure of airflow by which to make the correct diagnosis and judge the response to treatment.

Why is this? Perhaps the biggest reason is that traditionally as medical students and Family Practice Residents we received so little training in Respiriology. When one looks at the textbooks of Family Medicine there is very little information on Spirometry. There isn't a ready guide to the interpretation of Spirometry available. Hence, Family Physicians under-utilize Spirometry because they are not confident to read it. Most Family Physicians are familiar with interpreting simple Peak Expiratory Flow (PEF) measurements for home/outpatient management. However, PEF is much less accurate than Spirometry for office diagnosis and therapy.

COPD and Asthma constitute more than 20% of visits to Family Physicians. Meanwhile, the incidence of both COPD and Asthma are increasing. COPD is the fifth commonest cause of death in North America and is second only to Coronary Artery Disease as a cause of permanent disability over age 40\(^1\). Only 15 to 20% of all long-time smokers develop COPD. Using Spirometry, we can identify those smokers developing obstructive airways disease early. Smoking cessation can lead to a return of the rate of decline of the FEV\(_1\) to that of non-smokers within two years (see Appendix A). Also, early detection can lead to improved quality of life through rehabilitation programs.

Rising Asthma mortality is related to under-diagnosis, under-treatment with steroids, and failure of physicians to recognize the severity of the Asthma. It has been shown that proper emergency management will lead to fewer Emergency Room visits and fewer hospitalizations. This can only be accomplished with proper measurement of airflow using Spirometry because clinical signs of Asthma are poor predictors of objective spirometric values.

Steroids are probably under-utilized in the acute management of Asthma and COPD. Meanwhile, steroids are only of value to 15 to 20% of chronic COPD patients and those responders can only be identified using Spirometry. How many COPD patients are on inhaled steroids chronically without any proven benefit? Chronic Asthma, on the other hand, almost always responds to inhaled steroids and that needs to be followed with Peak Expiratory Flow measurements and Spirometry. How many Asthmatics are not on inhaled steroids that would benefit greatly? Studies have shown that we are over and under treating these
patients in large numbers.

The Expert Panel of the National Asthma Education Program as well as the International Consensus Report on the Diagnosis and Treatment of Asthma have recommended baseline Spirometry in all Asthmatics and periodically in selected patients to confirm home Peak Flow measurements (2,3).

The Canadian Asthma Consensus Conference has stated that objective measurements are needed to confirm the diagnosis of Asthma and assess Asthma severity. This can be obtained by any one of the following: FEV₁, PEF home measurement incorporating response to beta₂-agonist, or methacholine / histamine Challenge Test in the lab (4).

Antibiotics are often inappropriately prescribed to treat exacerbations of Asthma or worsening cough due to airway inflammation without any measurement of Spirometry. This treatment is often not effective and has contributed to the high cost of our health care and the rise of resistant organisms.

The Canadian Thoracic Society has recommended baseline Spirometry for early detection of COPD in patients with significant occupational exposure to respiratory irritants, smokers, patients with recurrent or chronic respiratory symptoms, and those with a family history of pulmonary disease (5). The American Thoracic Society states that Spirometry, both pre and post bronchodilator, is essential to confirm the presence and reversibility of airflow obstruction and to quantify maximum level of ventilatory function for the diagnosis of COPD (6).

Family Physicians need a rational approach to the management of these conditions and it should begin with proper measurement and interpretation of Spirometry.
COSTS OF TREATMENT

We can use the Ontario example to illustrate the costs of treatment. A recent study by Chan and associates (7) of Spirometry utilization in Ontario showed that OHIP billings for all flow studies in 1994 to 1995 was 14.13 million dollars. The proportionate billing was Family Doctors 30%, Internists/Respirologists 55%, and Pediatricians 11%. This expenditure increased by 36.9% from 1989-90 to 1994-95 exceeding the overall growth rate of 20.8% for all expenditures under OHIP. The rapid growth in utilization probably stems from Physicians following new guidelines for the diagnosis and monitoring of Asthma and COPD. However, we desperately need to educate our Family Doctors in the proper use and interpretation of Spirometry if we are going to get the value out of this significant expenditure. It is likely that Spirometry is still under-utilized in Ontario (8).

The OHIP fee for basic Spirometry is $16.20. The fee is almost doubled to $31.90 if you add a Flow Volume Loop. The addition of a post-bronchodilator Spirogram adds a further $8.10. Flow Volume Loops are not necessary for the majority of tests performed in Primary care settings and they have more errors in them and are therefore better carried out in hospital labs and not repeated more than once a year (8).

However, the costs of Spirometry are a fraction of the costs of treatment. The average cost for a month of treatment with inhaled steroids by metered-dose inhaler is $20. The average cost for a month of high dose inhaled steroid is $80. In Canada in 1996 we spent $152.9 million on Inhaled Steroids alone! That is an increase of 5% from 1995. If you add in the cost of beta mimetic and anticholinergic Metered-dose inhalers the total amount would be staggering. When you consider that as much as 30% of these prescriptions are not indicated because of the wrong diagnosis or failure to follow practice guidelines it more than justifies the cost of Spirometry!

**TABLE 1**

<table>
<thead>
<tr>
<th>INDICATIONS FOR SPIROMETRY</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Evaluate respiratory symptoms and signs</td>
</tr>
<tr>
<td>• Assess disease severity or response to treatment</td>
</tr>
<tr>
<td>• Pre-operative risk assessment</td>
</tr>
<tr>
<td>• Screen high risk patients</td>
</tr>
<tr>
<td>• Smokers &gt;20 pack years*</td>
</tr>
<tr>
<td>• Patients with disease or treatments affecting the lungs</td>
</tr>
<tr>
<td>• Workers in certain occupations</td>
</tr>
</tbody>
</table>

* Pack year is defined as: the packs of cigarettes smoked per day x number of years smoked  
  e.g. 1½ packs/day x 10 years = 15 pack years
The indications for Spirometry in primary care are listed in Table 1. Spirometry can be used to differentiate many symptoms such as cough, dyspnea, sputum production, exercise intolerance, wheezing, or chest pain. It will usually reveal the type of lung disease as either Restrictive or Obstructive which will lead to a prompt diagnosis in most cases.

Spirometry will allow accurate prescription of medication and the patient's response to treatment.

Preoperative Spirometry is useful in smokers, patients with known lung disease, the elderly, and those undergoing lung surgery.

In Family Practice it is important to screen high risk populations. Table 2 lists the most common Obstructive and Restrictive Pulmonary Disorders.

### Table 2

#### Common Obstructive Pulmonary Disorders

<table>
<thead>
<tr>
<th>Diffuse Airway Disease</th>
<th>Upper Airway Obstruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asthma</td>
<td>Foreign Body</td>
</tr>
<tr>
<td>COPD</td>
<td>Neoplasm</td>
</tr>
<tr>
<td>Bronchiectasis</td>
<td>Tracheal Stenosis</td>
</tr>
<tr>
<td>Cystic Fibrosis</td>
<td>Tracheomalacia</td>
</tr>
<tr>
<td></td>
<td>Vocal Cord Paralysis</td>
</tr>
</tbody>
</table>

| Parenchymal Disease    |                          |
| Emphysema              |                          |

#### Common Restrictive Pulmonary Disorders

| Parenchymal            | Pleural                  |
|                       | Effusion                 |
|                        | Fibrosis                 |
| Interstitial Lung Diseases | Chest Wall             |
| Fibrosis (i.e. Idiopathic, Connective Tissue Diseases, Post-radiation, Drug-induced) | Kyphoscoliosis |
| Granulomatosis (i.e. TB, Sarcoid) | Neuromuscular Diseases |
| Pneumoconiosis         | Trauma                   |
| Pneumonitis (i.e. Lupus, Scleroderma) | Extrathoracic          |
| Loss of Functioning Tissue | Abdominal Distension |
EQUIPMENT AND TESTING TECHNIQUE

There are two types of Spirometers available: volume-displacement and flow-sensing spirometers (pneumotachometers). Volume-displacement spirometers are the “gold-standard” but they are large and expensive machines usually only found in hospital testing facilities. Flow-sensing spirometers have become more common and accurate with the advent of micro-processors and improved design that can measure thousands of discrete flow samples per second. The results are computer analyzed. The machines are small and affordable for a group practice or shared office. However, some machines are better than others and it pays to shop around for the best quality unit for the money.

It is essential that the tester be well trained with the equipment. A good equipment supplier will provide instruction for you and your staff. It is not as important who does the testing (e.g. doctor, nurse, or respiratory therapist) as it is to do the test properly. The American Thoracic Society has issued recommendations (9) and the criteria for acceptability and reproducibility are summarized in Table 3. Weekly calibration with a standard three (3) Liter volume syringe is recommended in the office setting. The calibration syringe is usually purchased from the equipment supplier. The technique for proper accuracy/check calibration to ensure proper flow measurement is easy and detailed in the spirometer user’s manual.

Most of the time the patient is sitting for the test. Nose clips are recommended to prevent leaks. However, they are not essential and in fact one recent study (10) found that the nose clips did not change spirometric values in a clinically significant way.

Patient effort is the single most important factor in getting a good result. This requires enthusiastic coaching on the part of the tester. Maximal exhalation right from the start is critical to get a good result which will be reproducible with less than 5% variation. The tester should include a comment about patient effort and the quality of the test. A minimum of three and a maximum of eight of these maneuvers are performed until three curves are acceptable. Some chronic respiratory patients will be unable to perform three acceptable maneuvers and the single best result has to be used clinically. If a patient cannot perform successfully in the office, it may be worthwhile referring them to a hospital lab setting for further testing.

Children can usually perform spirometry after age 5 years. However, between the ages of 5-10 years, they can rarely hold their exhalation for more than three (3) seconds and practically speaking, we look for a two (2) second plateau.
AMERICAN THORACIC SOCIETY
CRITERIA FOR ACCEPTABILITY AND
REPRODUCIBILITY OF A SPIROGRAM

Acceptability Criteria
- Satisfactory effort
- No artifacts induced by coughing, glottic closure, or equipment problems
- Minimum of six seconds exhalation with a two second plateau
- At least three acceptable maneuvers

Reproducibility Criteria
- Largest FVC should be within 5% of the next largest FVC
- Largest FEV₁ should be within 5% of the next largest FEV₁
- Must meet criteria for acceptability

Reporting
- Report highest values of FEV₁ and FVC from any acceptable maneuver
- The above values do not need to be from the same maneuver
- The “best test” curve has the largest sum of FEV₁ and FVC
- Mid flows if reported should be derived from the “best test” curve
In general, the reference values of Morris and Crapo (11) are the most widely used for adults. Polger (12) is used for most pediatric testing. Other factors that influence the normal values are listed in Table 4.

The FVC, FEV₁, and the FEV₁/FVC ratio form the basis for interpretation. These definitions are outlined in Table 5. To quote American Pulmonologist, Dr. Thomas Petty: "These two parameters alone, the FVC and the FEV₁ are all that the clinician needs to assess patients with a wide variety of abnormalities. No other flow test offers any advantage and the compulsive recording of numerous other flow parameters not only serves to confuse, but also imposes a veil of mystery in contrast to the simplicity and practicality of spirometry in the daily practice of medicine." (13) Fortunately, most of the computerized numbers can be ignored and the clinician can focus on these three critical measurements to make the diagnosis.

(Text continued on page 9)

Table 4

<table>
<thead>
<tr>
<th>Factors That Influence Normal Values of Pulmonary Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td>Sex</td>
</tr>
<tr>
<td>Race</td>
</tr>
<tr>
<td>Posture</td>
</tr>
</tbody>
</table>
**DEFINITIONS OF TERMINOLOGY**

**FVC** (forced vital capacity in liters) The maximal volume of air exhaled using maximal effort following maximal inspiration. This is the most useful measurement for diagnosing and following restrictive lung disease. The normal range is higher than 80% of the predicted value.

**FEV₁** (forced expiratory volume in one second in liters) The volume of air exhaled during the first second. This is the most important measurement for following obstructive lung disease and determines the severity of airways obstruction. The normal range is 80% of the predicted value. The normal rate of decline in lung function due to aging is about 30 ml. loss of FEV₁ per year in adults. Smokers in whom COPD is developing have decreases in FEV₁ of 60-120 ml./year.

**FEV₁/FVC Ratio** The ratio is used to detect airways obstruction. As a rule of thumb, a ratio of less than 70% indicates an obstructive disorder in middle-aged adults. The spirometer should calculate the exact lower limit of the normal range for other ages.

**PEF** (peak expiratory flow in L/sec. or L/min.) The largest expiratory flow achieved using maximal forced effort, following maximal inspiration. Peak flow meters are useful for home monitoring of patients with asthma. Less than 80% of the patient’s personal best suggests obstruction, and less than 50% heralds an acute asthma attack.

**FEF 25-75%** (forced expiratory flow) The expiratory flow rate over the middle half of the FVC, the average flow from the point at which 25% of the FVC has been exhaled to the point at which 75% of the FVC has been exhaled. The FEF 25-75% was intended to reflect the portion of the curve that was most independent of the influence of patient effort, and was thought to relate to airflow in peripheral airways, where diseases of chronic airflow obstruction may begin. However, the FEF 25-75% is highly variable and depends on volume; it should not be used to diagnose or evaluate an obstructive impairment when it is the only functional abnormality. Low values may result from an even slightly submaximal effort, rather than from airflow obstruction.
The accompanying Diagnostic Flow Diagram (13.14) is useful to follow every time you interpret a Spirogram.

Start with the FEV₁/FVC ratio which will lead you on to either normal, obstructive or a restrictive pattern.

Obstructive patterns comprise the lion’s share of results in primary care. The FEV₁/FVC ratio will be reduced to less than 70%. This is the definition of an obstructive defect. The FEV₁ measurement will give you an idea as to the severity of the defect. If the FVC is normal, that is greater than 80% of predicted, then there is a pure obstructive defect. Generally, if the obstruction shows a significant reversal with a beta agonist, that is greater than 12% improvement, then the diagnosis is Asthma. The percent improvement is usually calculated automatically by the equipment. However, to understand it better, here is an example:

\[
\text{FEV}_1 \text{ pre beta agonist } 1.5 \text{L; post } 2.0 \text{L.} \\
\% \text{ change } \frac{0.5}{1.5} \times 100 = 33\%
\]

If there is no significant change then the diagnosis is likely COPD. Sometimes the differentiation is unclear because there are COPD patients who have a small element of reversibility. Also, some chronic Asthmatics may not respond to beta agonist at first because of severe inflammation.

If the FEV₁/FVC ratio is reduced and the FVC is low, then you have a combined obstructive or restrictive pattern to sort out. A patient with significant air-trapping and hyperinflation will have a reduced FVC. Thus, a bad Asthmatic may have a combined pattern that will greatly improve with beta agonist. A lack of response to a beta agonist demands further investigation with full pulmonary function testing with Carbon Monoxide (CO) diffusion and Lung Volume measurements. If the pattern is moderate to severe it will likely require referral to a Respirologist to properly evaluate it.

Restrictive patterns are not nearly as common in primary care as obstructive patterns. Therefore a normal FEV₁/FVC ratio with a low FVC immediately leads to a diagnosis of a restrictive pattern. A mild abnormality may only represent poor conditioning or obesity. However, a moderate to severe restrictive pattern deserves further pulmonary function testing with CO diffusion and Lung Volume measurement. These problems are uncommon and may signify a serious underlying disease (see Table 2). Referral to a Respirologist may be indicated.

(text continued on page 11)
Is FEV₁/FVC ratio low? (<70%)

- Yes → Obstructive defect
  - Is FVC low? (<80% pred)
    - Yes → Combined pattern of obstruction and restriction/or hyperinflation
      - Reversible obstruction** and improved FVC with β-agonist
        - No → Further testing with full PFTs* and consider referral if moderate to severe***
    - No → Pure obstruction
      - Reversible obstruction** with β-agonist
        - Yes → Suspect asthma
        - No → Suspect COPD****
  - No → Further testing with full PFTs* and consider referral if moderate to severe***
- No → Is FVC low? (<80% pred)
  - Yes → Restrictive pattern
  - No → Normal spirometry

Further testing with full PFTs* and consider referral if moderate to severe***

Adapted with permission from Criner (11)

* means Pulmonary Function Tests with CO Diffusion and Lung Volumes
** means > 12% and > 200 cc. improvement
*** see Table 6 for definitions of mild, moderate, and severe
**** Some chronic asthmatics will not respond to beta agonist initially.
Some COPD patients will show slight improvement with beta agonist.
Table 6 summarizes the categories of mild, moderate, and severe restriction and obstruction (15):

<table>
<thead>
<tr>
<th><strong>SEVERITY OF OBSTRUCTION</strong></th>
<th><strong>FEV&lt;sub&gt;1&lt;/sub&gt;</strong></th>
<th><strong>FVC</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mild</strong></td>
<td>&gt; 70% predicted</td>
<td>&gt; 65% to 80% predicted</td>
</tr>
<tr>
<td><strong>Moderate</strong></td>
<td>50% to 69% predicted</td>
<td>&gt; 50% to &lt; 65% predicted</td>
</tr>
<tr>
<td><strong>Severe</strong></td>
<td>&lt; 50% predicted</td>
<td>&lt; 50% predicted</td>
</tr>
</tbody>
</table>

**ACUTE INHALED BRONCHODILATOR RESPONSE**

<table>
<thead>
<tr>
<th></th>
<th><strong>Pre Bronchodilator</strong></th>
<th><strong>Post Bronchodilator</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FEV&lt;sub&gt;1&lt;/sub&gt;</strong></td>
<td>Normal/Reduced</td>
<td>12% and 200 ml. increase</td>
</tr>
<tr>
<td><strong>FVC</strong></td>
<td>Normal/Reduced</td>
<td>12% and 200 ml. increase</td>
</tr>
</tbody>
</table>
Most of the up-to-date Spirometers will give you a print out of the expiratory flow volume pattern. Although it is beyond the scope of this book to give a detailed analysis of these curves it is important to recognize the typical obstructive and restrictive patterns.

**GRAPH 1** illustrates the **NORMAL** pattern of airflow against time. Note the point at which the FEV₁ and the FVC are measured. This graph will also show you how long the patient performed the test, which should be 6 seconds whenever possible. If the duration of the test is too short than it may lead to a falsely low value for the FVC.
**GRAPH 2** illustrates the flow volume curve for a **NORMAL** subject. This demonstrates how critical it is to get a good starting point for an accurate Peak Expiratory Flow. This depends on patient effort and good coaching by the tester.

![Normal Expirator Flow Volume Curve](image)

**GRAPH 3** shows the curve when **OBSTRUCTION** is present. Note the decreased Peak Expiratory Flow and FEV₁. The curve demonstrates a concavity upward which will increase as the obstruction increases. A small concavity upwards may indicate mild obstruction even though the FEV₁ is still within normal limits.

![Obstruction](image)
**GRAPH 4** illustrates the curve with RESTRICTION. Note the relatively well-maintained Peak Expiratory Flow Rate with a rapidly decreasing flow to residual volume.

![Graph 4: Restriction](image)

**GRAPH 5** combines all three curves representing normal, obstructive, and restrictive curves for comparison.

![Graph 5: Normal, Obstruction and Restriction Compared](image)

These patterns only serve as a general guide for most patients.
**CLINICAL EXAMPLES**

I have deliberately chosen a variety of examples from the Office, Hospital, and Emergency settings. You will note that the extraneous numbers printed out in most reports have been eliminated and we have focused on the only values necessary to interpretation.

**PATIENT ONE**

<table>
<thead>
<tr>
<th></th>
<th>Predicted</th>
<th>Measured</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC liters</td>
<td>5.10</td>
<td>5.39</td>
<td>106%</td>
</tr>
<tr>
<td>FEV₁ liters</td>
<td>4.12</td>
<td>4.51</td>
<td>109%</td>
</tr>
<tr>
<td>FEV₁/FVC %</td>
<td>81%</td>
<td>84%</td>
<td>-</td>
</tr>
<tr>
<td>PEF liters/min</td>
<td>5.53</td>
<td>6.54</td>
<td>118%</td>
</tr>
<tr>
<td>FEF 25-75 liters/min</td>
<td>4.13</td>
<td>4.90</td>
<td>119%</td>
</tr>
</tbody>
</table>

**INTERPRETATION**

Normal Spirometry - Note the normal FEV₁/FVC ratio of 84%. The FVC is 106% of normal and the FEV₁ is 109% of predicted.
PATIENT TWO

Age: 56  
Height: 153 cm.  
Sex: female  
Ethnic Origin: Caucasian

<table>
<thead>
<tr>
<th></th>
<th>Pre Bronchodilator</th>
<th>Post Bronchodilator</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Predicted</td>
<td>Measured</td>
</tr>
<tr>
<td>FVC liters</td>
<td>2.71</td>
<td>2.89</td>
</tr>
<tr>
<td>FEV₁ liters</td>
<td>2.23</td>
<td>2.01</td>
</tr>
<tr>
<td>FEV₁/FVC %</td>
<td>82%</td>
<td>70%</td>
</tr>
<tr>
<td>PEF liters/min</td>
<td>3.22</td>
<td>2.16</td>
</tr>
<tr>
<td>FEF 25-75 liters/min</td>
<td>2.46</td>
<td>1.71</td>
</tr>
</tbody>
</table>

**INTERPRETATION**

Mild Obstruction with Reversibility - Note the FEV₁ /FVC ratio is 70% with a normal FVC at 106%. the FEV₁ is 90%. However, post-bronchodilator there is significant improvement in the FEV₁ of 18%. This patient has mild responsive Asthma.
### PATIENT THREE

**Age:** 32  
**Height:** 164 cm.  
**Sex:** female  
**Ethnic Origin:** Caucasian

<table>
<thead>
<tr>
<th>Measure</th>
<th>Pre Bronchodilator</th>
<th>Post Bronchodilator</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Predicted</td>
<td>Measured</td>
</tr>
<tr>
<td><strong>FVC</strong> liters</td>
<td>3.77</td>
<td>2.10</td>
</tr>
<tr>
<td><strong>FEV₁</strong> liters</td>
<td>3.21</td>
<td>1.15</td>
</tr>
<tr>
<td><strong>FEV₁/FVC %</strong></td>
<td>85%</td>
<td>55%</td>
</tr>
<tr>
<td><strong>PEF</strong> liters/min</td>
<td>3.90</td>
<td>2.58</td>
</tr>
<tr>
<td><strong>FEF 25-75</strong> liters/min</td>
<td>3.74</td>
<td>0.40</td>
</tr>
</tbody>
</table>

**INTERPRETATION**

Severe Obstruction with Reversibility - Note the reduced $\text{FEV}_1/\text{FVC}$ ratio at 55% and a reduced FVC at 56% and a reduced $\text{FEV}_1$ at 36% signifying a combined pattern. This was partially reversed with bronchodilator with a significant improvement of 28% in the $\text{FEV}_1$. This patient has Asthma and a strong family history of COPD as well.
**PATIENT FOUR**

**Age:** 59  
**Height:** 168 cm.  
**Sex:** male  
**Ethnic Origin:** Caucasian

<table>
<thead>
<tr>
<th></th>
<th>Pre Bronchodilator</th>
<th>Post Bronchodilator</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Predicted</td>
<td>Measured</td>
<td>%</td>
</tr>
<tr>
<td><strong>FVC</strong> liters</td>
<td>4.05</td>
<td>1.73</td>
<td>43%</td>
</tr>
<tr>
<td><strong>FEV₁</strong> liters</td>
<td>2.92</td>
<td>0.65</td>
<td>22%</td>
</tr>
<tr>
<td><strong>FEV₁/FVC</strong> %</td>
<td>72%</td>
<td>38%</td>
<td>-</td>
</tr>
<tr>
<td><strong>PEF</strong> liters/min</td>
<td>7.70</td>
<td>2.10</td>
<td>27%</td>
</tr>
<tr>
<td><strong>FEF 25-75</strong> liters/min</td>
<td>2.96</td>
<td>0.27</td>
<td>9%</td>
</tr>
</tbody>
</table>

**INTERPRETATION**

Severe Obstruction and Restriction Pattern - Note the markedly reduced FEV₁/FVC ratio at 38% and FVC at 43%. The FEV₁ is severely reduced to <1 liter or 22%. The post-bronchodilator results show an improvement in the FEV₁ from 0.65 liters to 0.81 liters which is 25% - but only 150 mls which is less than the 200 mls required for significant reversibility. This patient has severe COPD and Asthma and the lack of significant reversibility does not preclude a clinical response to a trial of bronchodilators. Further Pulmonary Function testing revealed a reduced CO Diffusion secondary to emphysema and increased lung volumes particularly the Total Lung Capacity and Residual Volume, indicating that the low FVC was not due to restrictive defect.
### Patient Five

- **Age:** 35
- **Height:** 159 cm.
- **Sex:** Female
- **Ethnic Origin:** Caucasian
- **Smoking History:** Yes
- **Quit:** One week ago
- **Bronchodilators:** Pre-test

<table>
<thead>
<tr>
<th></th>
<th>Pre Bronchodilator</th>
<th>Post Bronchodilator</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Predicted</td>
<td>Measured</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>FVC</td>
<td>liters</td>
<td>3.55</td>
</tr>
<tr>
<td></td>
<td></td>
<td>49%</td>
</tr>
<tr>
<td>FEV₁</td>
<td>liters</td>
<td>2.79</td>
</tr>
<tr>
<td></td>
<td></td>
<td>39%</td>
</tr>
<tr>
<td>FEV₁/FVC%</td>
<td>%</td>
<td>79%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>63%</td>
</tr>
<tr>
<td>PEF</td>
<td>liters/min</td>
<td>3.74</td>
</tr>
<tr>
<td></td>
<td></td>
<td>48%</td>
</tr>
</tbody>
</table>

**Interpretation**

Severe Obstruction with Reversibility (in the Emergency Department) - Note the mildly reduced FEV₁/FVC ratio at 63% while the FVC is only 49% and the FEV₁ is only 39%. This patient presented to the ER Department for the third time on antibiotics and not improving. The spirometry was done post-bronchodilator and the FEV₁ improved to 54% and the FVC to 70% of predicted. That's a 45% improvement in both FEV₁ and FVC. The patient was diagnosed with Asthma and started on steroids and sent home for follow-up in three days with their Family Doctor.
PATIENT SIX

Age: 44  
Height: 180 cm.
Sex: female  
Ethnic Origin: Caucasian

<table>
<thead>
<tr>
<th></th>
<th>Pre Bronchodilator</th>
<th>Post Bronchodilator</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Predicted</td>
<td>Measured</td>
</tr>
<tr>
<td>FVC liters</td>
<td>4.26</td>
<td>4.65</td>
</tr>
<tr>
<td>FEV₁ liters</td>
<td>3.29</td>
<td>2.60</td>
</tr>
<tr>
<td>FEV₁/FVC %</td>
<td>76%</td>
<td>56%</td>
</tr>
<tr>
<td>PEF liters/min</td>
<td>7.00</td>
<td>4.85</td>
</tr>
<tr>
<td>FEF 25-75 liters/min</td>
<td>3.49</td>
<td>1.27</td>
</tr>
</tbody>
</table>

INTERPRETATION

Mild Obstruction and little Reversibility - Note the FEV₁/FVC ratio is reduced to 56% confirming obstruction. The FVC is 109%, therefore no restriction. The FEV₁ is 79% of predicted so the defect is mild. There is only an 8% change in the FEV₁ post bronchodilator. This patient likely has COPD or inadequately treated Asthma with persistent airway.
**PATIENT SEVEN**

<table>
<thead>
<tr>
<th></th>
<th>Pre Bronchodilator</th>
<th>Post Bronchodilator</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Predicted</td>
<td>Measured</td>
</tr>
<tr>
<td>FVC  liters</td>
<td>3.15</td>
<td>2.40</td>
</tr>
<tr>
<td>FEV₁  liters</td>
<td>2.26</td>
<td>1.75</td>
</tr>
<tr>
<td>FEV₁/FVC %</td>
<td>71%</td>
<td>73%</td>
</tr>
<tr>
<td>PEF  liters/min</td>
<td>5.82</td>
<td>5.01</td>
</tr>
<tr>
<td>FEF 25-75 liters/min</td>
<td>2.44</td>
<td>1.20</td>
</tr>
</tbody>
</table>

**INTERPRETATION**

Mild Restriction - Note the normal FEV₁/FVC ratio of 73% with a mildly decreased FVC of 76%. There is no significant response to bronchodilator. Typically, this patient might be obese or have kyphoscoliosis of the thoracolumbar spine. A clinical correlation is required.
PATIENT EIGHT

Age: 32
Height: 180 cm.
Sex: male
Ethnic Origin: Caucasian

<table>
<thead>
<tr>
<th></th>
<th>Pre Bronchodilator</th>
<th>Post Bronchodilator</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Predicted</td>
<td>Measured</td>
</tr>
<tr>
<td>FVC liters</td>
<td>5.47</td>
<td>2.87</td>
</tr>
<tr>
<td>FEV(_1) liters</td>
<td>4.25</td>
<td>2.38</td>
</tr>
<tr>
<td>FEV(_1)/FVC %</td>
<td>77%</td>
<td>83%</td>
</tr>
<tr>
<td>PEF liters/min</td>
<td>9.83</td>
<td>6.53</td>
</tr>
<tr>
<td>FEF 25-75 liters/min</td>
<td>4.41</td>
<td>2.68</td>
</tr>
</tbody>
</table>

**INTERPRETATION**

Moderate Restriction - Note the normal FEV\(_1\)/FVC ratio of 83%. The FVC is reduced to 52% without change with bronchodilator. Further Pulmonary Function Testing and referral to a Respirologist is indicated depending on the clinical situation.
Screening Spirometry will identify those smokers developing COPD at an earlier stage when intervention can have its greatest benefit. One study in a Family Practice setting identified 17% of patients who smoked had COPD. Furthermore, 18% of patients who had a previous diagnosis of COPD were found to have normal Spirometry and were misdiagnosed. The information from Spirometry in their study lead to a change in the therapeutic regimens in 37% of the patients. It is useful to show patients the graph of FEV\textsubscript{1} decline with and without smoking cessation to help motivate them (see Appendix A).

Spirometric changes over time, particularly a rapid decline in the FEV\textsubscript{1}, are an important sign of increased morbidity and mortality from all causes\(\text{(17)}\).

When a patient has an FEV\textsubscript{1} of less than 1.5 liters it is worthwhile doing a set of blood gases and oximetry, at rest and with exercise, to assess their oxygen requirements. This is also the level of FEV\textsubscript{1} at which a therapeutic trial of steroids should be considered if not done before. The patient is usually given 30 - 40 mg. of prednisone per day for a minimum of two weeks to see if there is a significant improvement in the FEV\textsubscript{1} of 15%. A positive response will occur in 10 - 20% of severe COPD patients and they can be switched over to a high potency inhaled steroid or tapered down to the minimal effective dose of oral prednisone.

Spirometry probably should be done annually in patients with COPD and with any clinical deterioration.
Asthma

Patients should learn to use hand-held Peak Flow Meters as outpatients.

Ambulatory Peak Flow Monitoring is useful for the following (4, 18):
1. To help diagnose asthma, especially in exercise-induced asthma or workers with occupationally related respiratory symptoms and normal baseline spirometry.
2. To monitor effectiveness of treatment.
3. To warn of impending asthma attacks (i.e. <80% normal)
4. To allow the patient to assume more responsibility and control in disease management.

Nomograms for Peak Flow Measurements in adults are included in Appendix B.

Unfortunately the peak flow is very effort dependent and has twice the measurement variability of the FEV\textsubscript{1}. The FEV\textsubscript{1} is the most reproducible pulmonary flow variable and it varies inversely and linearly with the degree of airflow obstruction in adult Asthma and COPD patients. Therefore, Peak Flow Measurements are useful for home monitoring while Spirometry with the FEV\textsubscript{1} is much more accurate and helpful for office management.

The post-bronchodilator FEV\textsubscript{1} measures the best lung function that can be achieved on the day of the visit and therefore is the best value to compare in the office on a visit-to-visit basis for management. Improvement in the pre-bronchodilator FEV\textsubscript{1} may also indicate more stability and control of their Asthma with less variability in their airways obstruction.

Asthma management in the Emergency Department requires a systematic approach. Our Adult (age 15-55 years) Emergency Asthma Protocol from Orillia Soldiers Memorial Hospital is included in the Appendix C as an example. If the FEV\textsubscript{1} is less than 50% of predicted then the patient should receive IV steroids and further assessment with possible admission to hospital. If the FEV\textsubscript{1} is improved to greater than 50% of predicted then they can probably be sent home on oral prednisone for follow-up with their Family Doctor. This protocol has led to decreased visits to the ER Department and fewer admissions to hospital.

To reinforce the different treatment protocols for the management of Asthma versus COPD we have included treatment algorithms in Appendices D and E.
APPENDIX A

Effects of Smoking and Stopping Smoking on FEV$_1$

APPENDIX B

Normal Values of Peak Expiratory Flow

Adapted from original data of Gregg & Nunn, Brit Med J, Aug. 1973
APPENDIX C

Emergency Asthma Protocol:
Orillia Soldiers Memorial Hospital, Orillia, ON

Adult Asthma (15-55 yr., excludes COPD)

All patients have:
1. Peak flow - pre and post treatment by ER staff
2. Oximetry - automatic ABG's if SaO₂ < 90%
3. Emerg Rx - Duvent 1 amp by nebulizer or
   Ventolin 1 cc. & Atrovent 2 cc. by nebulizer*
4. Spirometry - if available

**ER Treatment**
- ABG's
- IV Methylprednisolone 125 mg.
  Q8H
  or Solucortef 500 mg. Q6H
- Reassess after 2-3 hr.

**Admission Guidelines**
- FEV₁ < 50% predicted
- pCO₂ > 40mmHg, pO₂ < 60mm.Hg
- Decreased LOC or lethargy
- Persistent respiratory distress
- Previous life-threatening asthma
- Deterioration on oral steroids
- 2nd ER visit in previous 48 hr.
- Poor social circumstances

**Admission Investigations**
- CBC, blood cultures, electrolytes
- EKG if HR > 120, hypotension or arrhythmia
- Theophylline level PRN
- IV on all patients
- Portable chest X-ray

**Discharge Guidelines**
- Consider Prednisone for
  40 mg. po & script 40 mg. OD for one week,
  taper as per F. Doctor advice with F/U
- Encourage home Peak Flow monitoring
- Followup with F. Doctor in 2-3 days

* Repeat Duvent or
  Ventolin/Atrovent by
  nebulizer Q 20 min. PRN
Appendix D

Treatment Algorithm For COPD Maintenance Therapy

Promote smoking cessation

Ipratropium bromide MDI

Adequate response

Suboptimal response

Frequent need for $\beta_2$-agonist use, switch to combination therapy ipratropium and salbutamol

Add $\beta_2$-agonist as needed

Adequate response

Suboptimal response

Add theophylline once or twice daily

Adequate response

Suboptimal response

Trial of oral steroids (prednisone) for 2 weeks in stable patients

Post-bronchodilator 
FEV₁ returns normal or nearly so

Consider using asthma treatment algorithm *

Post-bronchodilator FEV₁ increased at least 20 percent and at least 200 cc. but much less than normal

Try high dose inhaled steroids or alternate day oral steroids to maintain benefit

Discontinue oral (and inhaled) steroids

Post-bronchodilator FEV₁ unchanged


APPENDIX E

Asthma Algorithm

ASTHMA DIAGNOSIS BASED ON SYMPTOMS AND OBJECTIVE ASSESSMENT


SPIROMETRY in PRIMARY CARE

This physician guide was conceived as a quick reference tool for clinicians in primary care. It provides a synopsis of the necessary information to enable Family Physicians to interpret basic spirometry and incorporate it into their management of common lung diseases such as Asthma and COPD, in the office, Emergency department, and hospital.

The guide also helps the Family Physician decide when a patient needs further pulmonary function testing and a referral to a specialist.

Using this guide will allow Primary Care Physicians to make an accurate diagnosis of lung diseases and a rational approach to treatment based on Spirometry.

"Family physicians have long been waiting for clear information on spirometry ... Family physicians who do not use spirometry may feel encouraged to do so as the guidelines and recommendations will likely enhance their diagnostic and treatment skills"

Dr. Claude Renaud, CCFP, FCFP, Director, Department of Professional Affairs, The College of Family Physicians of Canada

"Dr. Lowry has produced an excellent approach to a neglected problem: using Spirometry in Primary Care. Spirometry will lead to the diagnosis of lung disease and is a very good thing to be doing."

Dr. Nicholas Anthonisen, Respirologist, Dean, The University of Manitoba

"The Guide to Spirometry for Primary Care Physicians is well written, very reasonable and relevant to Family Physicians. We are happy to endorse this document."

Dr. Meyer Balter, Respirologist, Standards Committee Chair, Canadian Thoracic Society

The College of Family Physicians of Canada
Le Collège des médecins de famille du Canada

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Boehringer Ingelheim
Committed to respiratory care