Disclosures
Definitions (working definitions)

- Spirometer: a device that measures the volume of air exhaled or inhaled out of/in to a person’s lungs
- Spirometry: the measurement of the volume of air exhaled from a person’s lungs
- Spirogram: a graphic depiction of the volume of air exhaled from a person’s lungs over a period of time
- VC (vital capacity): the amount of air that can be expelled from the lungs after a person’s deepest breath
- FVC (forced vital capacity): the amount of air that can be forcibly expelled from the deepest breath
- FEV1 (forced expiratory volume in 1 second): the amount of air that can be exhaled in 1 second with a forced exhalation
- FEV1/FVC: the ratio of the FEV1 to the FVC.
- FEF 25-75 (“midlflow”): average airflow middle of FVC maneuver
- Flow-volume loop: flow of exhaled air plotted against volume
Spirometer

volume-time curve (spirogram)
Spirogram

NORMAL VOLUME TIME CURVE

Volume (liters)

Time (seconds)
Forced Vital Capacity (FVC)

FVC = 4.0 L
Forced Expiratory Volume at 1 second (FEV1)

NORMAL VOLUME TIME CURVE

FVC = 4.0 L
FEV1 = 3.3 L
FEV1/FVC ratio

FVC = 4.0 L
FEV1 = 3.3 L

FEV1 ÷ FVC = 3.3/4.0 = 0.83 (83%)
Forced Expiratory Flow 25-75% (FEF 25-75%)
Flow Spirometers (pneumotachometer)

• Advantages
  – Measure flow directly
  – Portable
  – Easily cleaned, (often disposable)

• Disadvantages
  – Hypersensitive: small error in zero can produce large error in volume
normal flow-volume loop

- Peak flow
- TLC
- FEV1
- FVC
Definitions (working definitions)

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ON THE
CAPACITY OF THE LUNGS,
AND ON THE
RESPIRATORY FUNCTIONS,
WITH A VIEW OF ESTABLISHING A PRECISE AND EASY METHOD OF DETECTING DISEASE BY THE SPIROMETER.

By JOHN HUTCHINSON, Surgeon.

Communicated by GEORGE CURSHAM, M.D.,
one of the secretaries of the society.

Received January 22nd—Read April 28th, 1846.

1. The subject which I have the honour to bring before this Society, is the consideration of the functions of the organs of respiration, with reference both to health and disease, as deduced from the result of an extensive research.

Before commencing this investigation, it is advisable to ascertain what has been already done by others upon the same subject, in order that the observer may be directed to the points which most require examination, and be enabled to render more apparent the results of his own experiments.

To understand the mechanism and function of the thorax and its contents, demands essentially a knowledge of the circulation of the blood, the composition and pressure of the atmosphere. These subjects were so unknown to the ancients, that we are not surprised to find from their writings how little accurate knowledge they possessed respecting the functions of the respiratory organs.

It is no less curious than instructive to observe, that while their writings teem with refined and absurd hypotheses, how tenacious they were of yielding to the truth when light first began to glimmer upon the subject.
Hutchinson’s Spirometer

Diagram 26.
Position of the body in filling the chest before breathing into the Spirometer.

To measure the vital capacity of the lungs.

Med Chir Trans 1846; 29: 137-252

https://wiki.engr.illinois.edu/display/BIOE414/History+of+Spirometry Accessed 7/1/2013
Diagram 1.
The division of the thoracic movements.

Vital capacity
- Complemental air
- Breathing air
- Reserve air
- Residual air

Diagram 15.
Relative difference in the three stages of respiration.

- Ordinary: 80 inches.
- Expiration: 74 inches.
- Inspiration: 101 inches.
### Table of the Vital Capacity in relation to Height

<table>
<thead>
<tr>
<th>Height.</th>
<th>From Observation.</th>
<th>Regular Progression.</th>
<th>Height.</th>
<th>From Observation.</th>
<th>Regular Progression.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ft. in.</td>
<td>ft. in.</td>
<td>cub. in.</td>
<td>ft. in.</td>
<td>ft. in.</td>
<td>cub. in.</td>
</tr>
<tr>
<td>5 0 to 5 1</td>
<td>174</td>
<td>174</td>
<td>5 6 to 5 7</td>
<td>229</td>
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<tr>
<td>5 1 to 5 2</td>
<td>177</td>
<td>182</td>
<td>5 7 to 5 8</td>
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<td>230</td>
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<tr>
<td>5 2 to 5 3</td>
<td>189</td>
<td>190</td>
<td>5 8 to 5 9</td>
<td>237</td>
<td>238</td>
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<td>5 3 to 5 4</td>
<td>193</td>
<td>198</td>
<td>5 9 to 5 10</td>
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<td>246</td>
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<td>5 4 to 5 5</td>
<td>201</td>
<td>206</td>
<td>5 10 to 5 11</td>
<td>247</td>
<td>254</td>
</tr>
<tr>
<td>5 5 to 5 6</td>
<td>214</td>
<td>214</td>
<td>5 11 to 6 0</td>
<td>259</td>
<td>262</td>
</tr>
</tbody>
</table>

Med Chir Trans 1846; 29: 137-252
Low Lung Function in Young Adult Life Is Associated with Early Mortality

Figure 1. Survival curves for cardiopulmonary mortality by tertiles of FEV<sub>1</sub> percentage predicted at baseline. Low tertile: FEV<sub>1</sub> percentage predicted, <95.19%; medium tertile: FEV<sub>1</sub> percentage predicted, >95.19% and <106.36%; high tertile: FEV<sub>1</sub> percentage predicted, >106.36%.

In conclusion, in a long-term population-based cohort, we found that low levels of FEV<sub>1</sub> and, to a lesser extent, FVC achieved by the age of 21–35 years predict risk of early cardiopulmonary mortality.
Indications for Spirometry

Diagnosis

• evaluate symptoms
  – cough
  – dyspnea
  – wheezing

• evaluate signs
  – cyanosis
  – abnormal breath sounds
  – chest deformity

• evaluate abnormal laboratory tests
  – hypoxemia
  – hypercarbia
  – polycythemia
  – abnormal chest imaging
Indications for Spirometry

• measure the effect and progression of disease on pulmonary function
• assess therapeutic intervention
  – inhalers
  – systemic medications (corticosteroids, immunomodulators)
• assess pre-operative risk
  – lung resection
  – pneumonectomy
• assess health status before beginning strenuous physical activity programs
• screening individuals at risk for the development of pulmonary disease
  – toxic exposures (occupational, disasters, medications)
  – Smokers (with symptoms and/or if > 45 y.o.)
“COPD is easily detected in its preclinical phase using spirometry, and successful smoking cessation (a cost-effective intervention) prevents further disease progression. This consensus statement recommends the widespread use of office spirometry by primary-care providers for patients ≥ 45 years old who smoke cigarettes.”
Byssinosis
% change FEV1 by respirable dust level in a 16-man panel of cotton cardroom workers exposed to raw cotton and steamed cotton, 1971-1972.

Occupational Safety and Health Cotton Dust Standard
(29 CFR 1910.1043)

• 1978 – Cotton Dust Standard established
• Based on exposure – response relationship between cotton dust particle concentration and lung function impairment
Permissible Exposure Limit (PEL)

- the amount of dust that a person can be exposed to in an 8-hour work shift over their working life without adverse health effects
PEL Cotton Dust
(29 CFR 1910.1043)

- 200 micrograms per cubic meter of lint-free respirable dust averaged over an eight-hour period in yarn manufacturing
- 750 micrograms per cubic meter of lint-free respirable dust over an eight-hour period of slashing and weaving
- 500 micrograms per cubic meter of lint-free respirable dust over an eight-hour period in waste houses and yarn manufacturing areas where exposure to lower grade washed cotton occurs.

“In any workplace where cotton dust is present there must be a medical surveillance program for all employees exposed to cotton dust. Examinations must be done by or under the direction of a licensed physician. People administering the pulmonary function breathing tests must have attended a course approved by the National Institute for Occupational Safety and Health (NIOSH).”

Test results are compared to a set of predicted tables based on a person’s age, height, sex and race. Generally, tests are considered to be within the normal range if they are 80 percent or greater of the predicted value. The initial determinations should be made prior to entering the workplace on the first day worked and after having no cotton dust exposure for at least 35 hours. The pulmonary function tests will be repeated during the shift, at least four hours, but not longer than 10 hours after the first test. These tests are then compared for changes. If there is a decrease of 5 percent or greater on the second after-exposure test, it may indicate a reaction to cotton dust. Each employee will be assigned a byssinosis grade based on his or her response to the respiratory questionnaire.
Other occupational exposures that require assessment of lung function

- Title 29, Part 1915.1001: **Asbestos.** If possible exposure, surveillance including spirometry

- Title 29, Part 1910.1028: **Benzene containing petrochemicals.** If respirators required more than 30 days per year, then spirometry required every 3 years.

- Title 20 CFR part 718.204: **Coal dust exposure.**
New § 37.90 provides the scope of the provisions in Subpart—Spirometry Examinations, and is amended to clarify the purpose of this subpart. Under this subpart, coal mine operators are required to provide spirometry examinations to each current and new coal miner, using medical facilities approved by NIOSH according to the standards established in this subpart.
(2) Medical criteria. In the absence of contrary probative evidence, evidence which meets the standards of either paragraphs (b)(2)(i), (ii), (iii), or (iv) of this section shall establish a miner's total disability:

(i) Pulmonary function tests showing values equal to or less than those listed in Table B1 (Males) or Table B2 (Females) in Appendix B to this part for an individual of the miner's age, sex, and height for the FEV1 test; if, in addition, such tests also reveal the values specified in either paragraph (b)(2)(i)(A) or (B) or (C) of this section:

(A) Values equal to or less than those listed in Table B3 (Males) or Table B4 (Females) in Appendix B of this part, for an individual of the miner's age, sex, and height for the FVC test, or

(B) Values equal to or less than those listed in Table B5 (Males) or Table B6 (Females) in Appendix B to this part, for an individual of the miner's age, sex, and height for the MVV test, or

(C) A percentage of 55 or less when the results of the FEV1 test are divided by the results of the FVC test (FEV1/FVC equal to or less than 55%).
Indications for Spirometry

• disability
  – assess individuals for medical/legal reasons
  – assess patients as part of a rehabilitation program
  – assess risks as part of an insurance evaluation

• public health
  – epidemiological surveys
  – clinical research
  – derivation of reference equations
<table>
<thead>
<tr>
<th>CLASS</th>
<th>CLASS 0</th>
<th>CLASS 1</th>
<th>CLASS 2</th>
<th>CLASS 3</th>
<th>CLASS 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHOLE PERSON IMPAIRMENT RATING (%)</td>
<td>0</td>
<td>2%-10%</td>
<td>11%-23%</td>
<td>24%-40%</td>
<td>45%-65%</td>
</tr>
<tr>
<td>SEVERITY GRADE (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Mineral)</td>
<td>(A B C D E)</td>
<td>(A B C D E)</td>
<td>(A B C D E)</td>
<td>(A B C D E)</td>
<td>(A B C D E)</td>
</tr>
<tr>
<td>HISTORY</td>
<td>No current symptoms and/or intermittent Dyspnea that does not require treatment</td>
<td>Dyspnea controlled with intermittent or continuous treatment</td>
<td>Constant mild Dyspnea despite continuous treatment</td>
<td>Constant moderate Dyspnea despite continuous treatment</td>
<td>Constant severe Dyspnea despite continuous treatment</td>
</tr>
<tr>
<td>PHYSICAL FINDINGS</td>
<td>No current signs of disease</td>
<td>Physical findings not present with continuous treatment</td>
<td>Constant mild physical findings</td>
<td>Constant moderate physical findings</td>
<td>Constant severe physical findings</td>
</tr>
<tr>
<td>OBJECTIVE TESTS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FVC</td>
<td>FVC ≥80% of predicted and/or FVC ≥80% of predicted</td>
<td>FVC between 70% and 79% of predicted</td>
<td>FVC between 60% and 69% of predicted</td>
<td>FVC between 50% and 59% of predicted</td>
<td>FVC below 50% predicted and/or FEV1 below 45% of predicted</td>
</tr>
<tr>
<td>FEV1</td>
<td>FEV1 ≥80% of predicted and/or FEV1 ≥80% of predicted</td>
<td>FEV1 between 65% and 79% of predicted</td>
<td>FEV1 between 64% and 55% of predicted</td>
<td>FEV1 between 45% and 54% of predicted</td>
<td>FEV1 below 45% of predicted</td>
</tr>
<tr>
<td>FEV1/FVC (%)</td>
<td>FEV1/FVC (%) ≥ lower limits of normal and/or (≥75% of predicted)</td>
<td>DLco ≥75% of predicted and/or DLco ≥75% of predicted</td>
<td>DLco between 65% and 74% of predicted and/or DLco between 65% and 74% of predicted</td>
<td>DLco between 45% and 54% of predicted and/or DLco between 45% and 54% of predicted</td>
<td>DLco below 45% of predicted</td>
</tr>
<tr>
<td>Vo2 max</td>
<td>&gt;25 mL/(kg·min) or &gt;7.1 METS and/or &gt;21 mL/(kg·min) or &gt;6.1-7.1 METS</td>
<td>&gt;22 and 25 mL/(kg·min) or &gt;6.1-7.1 METS</td>
<td>&gt;21 and 18 mL/(kg·min) or 5.1-6.0 METS</td>
<td>&gt;17 and 15 mL/(kg·min) or 4.3-5.0 METS</td>
<td>&lt;15 mL/(kg·min) or &lt;4.3 METS</td>
</tr>
</tbody>
</table>

* FVC indicates forced vital capacity; FEV1, forced expiratory volume in the first second; DLco, diffusion capacity for carbon monoxide; Vo2 max, maximum oxygen consumption; and METS, metabolic equivalents (multiples of resting oxygen uptake).
<table>
<thead>
<tr>
<th>CLASS</th>
<th>CLASS 0</th>
<th>CLASS 1</th>
<th>CLASS 2</th>
<th>CLASS 3</th>
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</tr>
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<td>WHOLE PERSON IMPAIRMENT RATING (%)</td>
<td>0</td>
<td>2%-10%</td>
<td>11%-23%</td>
<td>24%-40%</td>
<td>45%-65%</td>
</tr>
</tbody>
</table>

| SEVERITY GRADE (%) | 2 4 6 8 10 (A B C D E) (Minimal) | 11 14 17 20 23 (A B C D E) (Mild) | 24 28 32 36 40 (A B C D E) (Moderate) | 45 50 55 60 65 (A B C D E) (Severe) |

| OBJECTIVE TESTS | FVC ≥80% of predicted and FEV₁ ≥80% of predicted and FEV₁/FVC (%) > lower limits of normal and/or (>75% of predicted) | FVC between 70% and 79% of predicted or FEV₁ between 65% and 79% of predicted or FEV₁/FVC (%) > lower limits of normal and/or (>75% of predicted) | FVC between 60% and 69% of predicted or FEV₁ between 64% and 55% of predicted or FEV₁/FVC (%) > lower limits of normal and/or (>75% of predicted) | FVC between 50% and 59% of predicted or FEV₁ between 45% and 54% of predicted or FEV₁/FVC (%) > lower limits of normal and/or (>75% of predicted) | FVC below 50% predicted or FEV₁ below 45% of predicted |

Indications for Spirometry

**Diagnosis**

- evaluate symptoms
  - cough
  - dyspnea
  - wheezing
- evaluate signs
  - cyanosis
  - abnormal breath sounds
  - chest deformity
- evaluate abnormal laboratory tests
  - hypoxemia
  - hypercarbia
  - polycythemia
  - abnormal chest imaging
“All That Wheezes Is Not Asthma” (or COPD)!

David A. Kaminsky, MD, FCCP
Burlington, VT

This famous quote was made by Chevalier Jackson in the Boston Medical Quarterly in 1865. At the time, Jackson, an otolaryngologist, was concerned about foreign body aspiration causing wheezing and being misdiagnosed as asthma. Today, this adage reminds us that there are many causes of wheezing and shortness of breath besides the common and classic diagnosis of asthma. Among where spirometry is normal. Nevertheless, we need to remember that spirometry remains one of the best available, objective measures we have of defining the “O” in COPD so that we may render the most accurate and appropriate diagnosis in our patients who are short of breath or wheeze.

P140 Is it really Asthma? - appropriate assessment and testing is important for accurate diagnosis.

S. Toor; S. Akram; K. Al Mazrouei; A. Al Zaabi; I. Saleem
Author and Funding Information

Asthma is common in United Arab Emirates with an estimated prevalence of 10%. A significant area of country comprises of desert and dust storms are common. Weather is extremely hot/humid and exposure to dust is a risk factor for airways disease. There is no objective evidence to back up estimated prevalence of 10%. General practitioners have a tendency to overdiagnose asthma without appropriate testing. A significant number of patients are wrongly diagnosed with Asthma in early childhood and they carry this diagnosis throughout their life.

National military service has been made mandatory for young Emirati males, aged 19 to 34 years. During health screening we have come across a huge patient population who has been labeled with a diagnosis of Asthma.

Aim of this study was to identify patients who have been wrongly diagnosed with Asthma and to document true prevalence of Asthma in this group.

Methods: Patients with Asthma identified during health screening for national service are referred to the Pulmonology department in Zayed Military Hospital for further assessment. These patients underwent clinical assessment by consultant pulmonologists who arranged for pre and post bronchodilator spirometry. Clinical assessment included symptoms of cough, wheeze, chest tightness, night time symptoms, exercise tolerance, use of rescue inhalers, hospitalization and smoking history. Patients who had a high clinical suspicion but no bronchodilator response on spirometry were subjected to Methacholine challenge test.
<table>
<thead>
<tr>
<th>Diagnosis before spirometry</th>
<th>Diagnosis after spirometry</th>
<th>Patients n</th>
</tr>
</thead>
<tbody>
<tr>
<td>No diagnosis</td>
<td>Asthma</td>
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<tr>
<td></td>
<td>COPD</td>
<td>60</td>
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<td>Other</td>
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<tr>
<td>Asthma</td>
<td>Asthma</td>
<td>34</td>
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<tr>
<td></td>
<td>COPD</td>
<td>31</td>
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<tr>
<td>COPD</td>
<td>Asthma</td>
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<td></td>
<td>COPD</td>
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<tr>
<td>Bronchiectasis</td>
<td>Bronchiectasis</td>
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<td>All diagnoses</td>
<td>Asthma</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td>COPD</td>
<td>139</td>
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<tr>
<td></td>
<td>Bronchiectasis</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>2</td>
</tr>
</tbody>
</table>

COPD: chronic obstructive pulmonary disease.
Diagnosis of Asthma

Diagnosis of asthma, the clinician must symptoms of recurrent obstruction or airways are present; airflow is partially reversible; and tests are excluded.

- Episodic symptoms of airflow obstruction or airway hyperresponsiveness are present.

- Airflow obstruction is at least partially reversible, measured by spirometry. Reversibility is determined by an increase in FEV₁ of >200 mL and ≥12 percent from baseline measure after inhalation of short-acting beta₂-agonist (SABA). Some studies indicate that an increase of ≥10 percent of the predicted FEV₁ after inhalation of a SABA may have higher likelihood of separating patients who have asthma from those who have chronic obstructive pulmonary disease (COPD).
Asthma:

- Recurring and variable symptoms
- Airflow limitation with reduced FEV₁/FVC
- Positive bronchodilator reversibility test
- Positive bronchial challenge test

Global Initiative for Chronic Obstructive Lung Disease

Figure 2.1. Pathways to the diagnosis of COPD

SYMPTOMS
- Shortness of breath
- Chronic cough
- Sputum

RISK FACTORS
- Host factors
- Tobacco
- Occupation
- Indoor/outdoor pollution

SPIROMETRY: Required to establish diagnosis

Conducting Airways

Physiology: FVC

• Flow (Pouiseuille’s law)
  – Airway diameter
    • Asthma: thickened basement membrane, matrix, hypertrophic musculature
    • Airway compliance
      – Airway structure (abnormal in bronchiectasis and tracheomalacia)
      – Supporting parenchymal stroma (abnormal in emphysema)
  – Laminar vs turbulent flow
    • Secretions
  – Dynamic compression
The entire point of the next slide is that the rate of flow of air in the airways is related to the 4th power of the radius. This means that even small changes in the size of the airways have very large effects on the flow of air in the lungs. **AND DON’T WORRY ABOUT THE MATH**
Laminar Flow and Pouiseuille’s Law

\[ \text{Volume Flowrate} = \frac{p_1 - p_2 \times r^4}{\frac{8}{\pi} \times v \times L} \]

- \( p_1 - p_2 = \text{pressure difference} \)
- \( r = \text{radius} \)
- \( v = \text{viscosity} \)
- \( L = \text{length of tube} \)
Laminar Flow and Pouiseuille’s Law

\[ p_2 - p_1 = \text{pressure difference} \]

\[ r = \text{radius} \]
\[ v = \text{viscosity} \]
\[ L = \text{length of tube} \]
Obstructive lung diseases

emphysema  bronchitis  asthma

West, JB. Pulmonary Pathophysiology – the essentials.  1987
Performing Valid Spirometry
Relative and absolute contraindications to PFTs

- Infectious risk (TB, Influenza)
- Hemoptysis (coughing blood)
- Severe SOB - (Can't hold breath for 10 seconds)
- Severe cough
- Chest, abdominal, oral, or facial pain
- Stress Incontinence
- Inability to cooperate (dementia/confusion/language barrier)
- Medically unstable
### Relative and absolute contraindications to Spirometry

<table>
<thead>
<tr>
<th>Contraindication</th>
<th>Reason to avoid lung function testing*</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoracic/abdominal surgery</td>
<td>Rupture site of injury, avoid pain, discomfort</td>
<td>Relative</td>
</tr>
<tr>
<td>Brain, eye, ear, ENT surgery</td>
<td>Rupture site of injury, avoid pain, discomfort</td>
<td>Relative</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>Worsen pneumothorax, avoid discomfort and pain</td>
<td>Relative</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>Induce further infarction leading to cardiac arrest</td>
<td>Absolute/relative</td>
</tr>
<tr>
<td>Ascending aortic aneurysm</td>
<td>Rupture of aneurysm, catastrophic/fatal event</td>
<td>Absolute/relative</td>
</tr>
<tr>
<td>Haemoptysis</td>
<td>Pulmonary emboli or myocardial infarction</td>
<td>Relative</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>Death, hypoxia leading to respiratory failure</td>
<td>Absolute/relative</td>
</tr>
<tr>
<td>Acute diarrhoea</td>
<td>Discomfort, embarrassment, infection risk</td>
<td>Relative</td>
</tr>
<tr>
<td>Angina</td>
<td>May lead to cardiac arrest in severe cases, discomfort</td>
<td>Absolute/relative</td>
</tr>
<tr>
<td>Severe hypertension (systolic &gt;200 mm Hg, diastolic &gt;120 mm Hg)</td>
<td>Risk of blackout/collapse, rupture of cerebral blood vessels, etc.</td>
<td>Measure blood pressure before tests if suspected</td>
</tr>
<tr>
<td>Confused/demented patients</td>
<td>Lung function tests are volitional and need patient cooperation</td>
<td>Balance need for test against difficult in obtaining results</td>
</tr>
<tr>
<td>Patient discomfort</td>
<td>Vomiting, diarrhoea, cold sores, common cold</td>
<td>Wait until main symptoms abate</td>
</tr>
<tr>
<td>Infection control issue</td>
<td>Contagious infections (norovirus, tuberculosis, flu)</td>
<td>Wait until main symptoms abate</td>
</tr>
</tbody>
</table>

*Sometimes the risk may be necessary as a preoperative assessment for life-saving surgery.
Recommendation: absolute, lung function testing should be avoided in most cases; relative, judge each case on its merits.

Cooper BG. Thorax (2010). doi:10.1136/thx.2010.139881
Patient preparation for PFTs

• Instructions to patient prior to the study:
  – Do not use LABA w/in 12 hours (Spiriva 24 hrs), SABA w/in 4 hours
  – Avoid smoking (at least 1 hour prior to study)
  – No heavy meal w/in 2 hours of the test
  – Avoid heavy exercise (w/in 30 min before the test)
  – Avoid tight clothing

• Technician to review these issues, delay the study if necessary
  – Medical issues/symptoms
  – URI – delay by 4 weeks
  – Document steroids, bronchodilators and last use of bronchodilators
Optimal Conditions for Spirometry

• Patient and tech:
  – speak same language,
  – have good rapport, and
  – are both highly motivated

• Excellent equipment, calibration verified

• Previous study before patient was exposed or became ill for comparison
FVC Maneuver

• Instructions – explain the test
• Before starting:
  – Standing vs sitting (standing FVC > Sitting FVC)
  – Loosen tight clothing
  – Sit straight and don’t slump
  – Feet flat on floor
  – Elevated chin and neck
  – Nose clip
  – Be sure teeth and tongue are not blocking mouthpiece
  – Tight seal with lips
FVC Maneuver

• Demonstrate
• Emphatic coaching
• Several systems and ways to do this
  – Closed systems – with loop
    • Breath in and out slowly, then take as deep a breath as you can and **blast it out!!!!!!** – when I tell you, suck the air back in as hard as you can until your lungs are completely filled again
  – Open systems - FVC with no loop
    • Take as deep a breath as you can, put the mouthpiece in you mouth **and blast it out!!!!!!!**
Valid spirometry must meet criteria for:

- **Acceptability**
- **Repeatability**
Forced Vital Capacity Maneuver (FVC)

Acceptability

- vigorous effort – usually requires:
  - maximal inspiration
  - vigorous encouragement by tech
- start of test criterion: no hesitation
  - explosive (“blast it out!!!!!”) exhalation
  - “extrapolated volume”
- middle of test: smooth expiratory effort
  - no cough in 1st second,
  - no leak,
  - no obstruction
- end of test criteria:
  - ≥ 6 seconds long – to maximal exhalation
  - plateau (< 0.025 liters in the last second)

Eur Respir J 2005; 26: 948–968
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  - plateau (< 0.025 liters in the last second)

Eur Respir J 2005; 26: 948–968
Acceptable VT Curve
Acceptable FV Loop

Acceptable FV Loop

ATS/ERS Minimum Size Instrument Display

- Volume Scale ≥ 5 mm/L
- Flow Scale ≥ 2.5 mm/L/s
- Time Scale ≥ 5 mm/s

* Complies with ANSI ISO 25672 aspect ratio requirements.

Townsend, MC. 2011. JOEM 53:569-84
Acceptable VT Curve
Acceptability (start of test):
extrapolated volume – hesitation

Acceptable
Start of Test
Acceptability (start of test):
extrapolated volume – hesitation - error
Acceptability (start of test):
extrapolated volume – hesitation - error
Acceptability (start of test):
extrapolated volume – hesitation - error
Acceptability (start of test):
extrapolated volume – hesitation - error
Acceptability (start of test): extrapolated volume – hesitation - error
Acceptability (start of test):
extrapolated volume – hesitation - error
Acceptability (start of test): extrapolated volume – hesitation - error

• The “blast it out” criterion (hesitation)
• The extrapolated volume should be less than:
  – 0.15 L or....
  – 5% of the FVC (whichever is greater)
Acceptability (start of test): extrapolated volume – hesitation - error

$FVC = 2.65 \, \text{L}$
$EV = 0.35 \, \text{L} \ (13\%)$
Acceptability (start of test):
extrapolated volume – hesitation - error

Notice peak flow occurs at large volume.
Forced Vital Capacity Maneuver (FVC) 

**Acceptability**

- vigorous effort – usually requires:
  - maximal inspiration
  - vigorous encouragement by tech

- start of test criterion: no hesitation
  - explosive ("blast it out!!!!!!") exhalation
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- middle of test: smooth expiratory effort
  - no cough in 1st second,
  - no leak,
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  - ≥ 6 seconds long – to maximal exhalation
  - plateau (< 0.025 liters in the last second)

Eur Respir J 2005; 26: 948–968
Forced Vital Capacity Maneuver (FVC)

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• vigorous effort – usually requires:
  – maximal inspiration
  – vigorous encouragement by tech

• start of test criterion: no hesitation
  – explosive ("blast it out!!!!!!") exhalation
  – “extrapolated volume”

• middle of test: smooth expiratory effort
  – no cough in 1st second,
  – no leak,
  – no obstruction

• end of test criteria:
  – ≥ 6 seconds long – to maximal exhalation
  – plateau (< 0.025 liters in the last second)

Eur Respir J 2005; 26: 948–968
Acceptability (end of test): plateau

ATS/ERS criterion: $< 0.025 \, \text{L in final 1 second}$
Normal VT Curve

Volume (liters)

Time (seconds)
Acceptability:
glottic closure
Acceptability (end of test): early termination (< 6 sec)
Forced Vital Capacity Maneuver (FVC) 

Acceptability

• vigorous effort – usually requires:
  – maximal inspiration
  – vigorous encouragement by tech
• start of test criterion: no hesitation
  – explosive (“blast it out!!!!!”) exhalation
  – “extrapolated volume”
• middle of test: smooth expiratory effort
  – no cough in 1st second,
  – no leak,
  – no obstruction
• end of test criteria:
  – ≥ 6 seconds long – to maximal exhalation
  – plateau (< 0.025 liters in the last second)
Acceptability:
cough in 1\textsuperscript{st} second
Acceptability: cough in 1st second
Acceptability: Inadequate inhalation
Acceptability: variable effort
Acceptability: variable effort
Get Valid Spirometry Results EVERY Time

A Valid Test has:
3 or More Good Curves
and Repeatable FVC and FEV1

*The most current American Thoracic Society/International Organisation for Standardization (ATS/ISO) standards

HOW TO CORRECT TEST ERRORS

**Poor Initial Effort**
Cough blast not HARDER

**Inhalation**
Slow Study: Large Expiratory Volume
Delete curve, Cough, Blast BETTER

**Gas in First Second**
Delete curve, Correction: Try a drink of water

**Incomplete Inflation**
Cough: Take a DEEPER breath

**No Plateau Before 15 Seconds**
Cough: Keep blowing until told to stop

**Inconsistent Effort**
Cough: One continuous blast and keep blowing

**Partially Blown Off**
Cough: Position mouthpiece between teeth and on top of tongue, close ears, don't hold

**Glistening Glue or Breath Holding**
Cough: Initial BIG BLOW then RELAX and keep blowing

**Lock**
Correction: Check equipment and connection

**Negative Zero Flow Error**
Correction: No Flow through sensing mechanism on spirometer sensing device

**Positive Zero Flow Error**
Correction: Re-line through sensing mechanism on spirometer sensor
Hold nose-as-air upright during test

**Extra Breaths**
Correction: DELETE CURVE! Use nose clips and lips tight by sealed

Delivering on the Nation’s promise: Safety and health at work for all people through research and prevention.

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

DHHS (NIOSH) Publication No. 201-1-135

SAFER • HEALTHIER • PEOPLE™

NIOSH (NIOSH) Publication No. 201-1-135

CDC

NIOSH
Valid spirometry must meet criteria for:

• **Acceptability**

• **Repeatability**

Eur Respir J 2005; 26: 948–968
Forced Vital Capacity Maneuver (FVC)

Repeatability

• Need 3 acceptable maneuvers (though only 2 used):

• Largest FVC and second largest FVC must not vary by more than 0.15 Liters

AND

• Largest FEV1 and second largest FEV1 must not vary by more than 0.15 Liters

• (If FVC is < 1.0 Liters volumes need to be within 1.0 liter)

Eur Respir J 2005; 26: 948–968
Repeatability

Repeatable Test
3 Acceptable Maneuvers
Repeatability

Repeatable Test
3 Acceptable Maneuvers
Repeatability

3 Acceptable Maneuvers
Repeatability

Non-Repeetable Test
3 Acceptable Maneuvers
Error Codes

**Spirometry**

- Extrapolated volume
- **000** — six second exhalation
- End of test plateau

FEV1 repeatability

FVC repeatability

PEF repeatability

- **000000** — six second exhalation
- Extrapolated volume
- End of test plateau
# Error Codes

**Date:** 08/27/10

- **Temp:** 23
- **Physician:** Mahapatra
- **Technician:** Jocelyne
- **Quit:** No
- **Medication Set 1:** Album

---

**Patient Information:**

- **Age:** 55  
- **Birth Date:** 03/25/55  
- **Gender:** Male  
- **Height (in):** 70  
- **Weight (lb):** 245  
- **BMI:** 35.16  
- **Race:** African-American  
- **Diagnosis:** COPD  
- **Smoker:** Yes  
- **How Long:** 23

---

## Spirometry

<table>
<thead>
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<th>Test</th>
<th>Value 1</th>
<th>Value 2</th>
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<th>CI</th>
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<td>FEV1/SVC %</td>
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Test Information
Session Quality: Pre: A; FEV1 Var=0.02L (0.5%); FVC Var=0.05L (0.9%)
Normal Spirometry (Interpretation: GOLD(2008)/Hardie)

Test Results
NHANES III

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</tr>
</tbody>
</table>

Problem: Patient may not have exhaled completely. Detailed criteria:Expiration time less than 2 seconds, OR volume in the last 0.5 seconds of the expiration more than 100 ml. (Message ID=4)

Solution: The patient must exhale longer and force as much air as possible out of his or her lungs.

Clapp, William / 9101320  12:30:33 AM
Patterns of impairment

- Restrictive
- Obstructive
- Mixed
Restrictive Defects
size of lung reduced to the point of impairment

• Interstitial lung disease (reduced compliance - "stiff")
  – Interstitial pneumonitis
  – Pulmonary fibrosis
  – Pneumoconiosis
  – Granulomatous
  – Pulmonary edema

• Infiltrative
  – malignancy

Adapted: WM Gold, 1994
Restrictive Defects
size of lung reduced to the point of impairment

- Space occupying lesions
  - tumor
  - cyst
- Pleural
  - pneumothorax,
  - effusion
  - fibrothorax
- Chest Wall
  - scoliosis
  - kyphosis
  - obesity
- Abdominal
  - ascites
  - pregnancy

Adapted: WM Gold, 1994
Patterns of Impairment
Restrictive Defects

- FEV1 low
- FVC usually low
- FEV1/FVC normal or high
- Midflows normal or high
Patterns of Impairment
Restrictive Defects

• “...the pattern of a reduced VC and a normal or even slightly increased FEV1/VC is often caused by submaximal inspiratory or expiratory efforts and/or patchy peripheral airflow obstruction, and a reduced VC by itself does not prove a restrictive ventilatory defect. It is associated with a low TLC no more than half the time.”

• “A restrictive ventilatory defect is characterized by a reduction in TLC below the 5th percentile of the predicted value, and a normal FEV1/VC.”

Eur Respir J 2005; 26: 948–968
Patterns of Impairment
Obstructive Defects

Lower/peripheral (small and medium) airways
• Intrinsic obstruction (lumen) small and medium airways
  – Asthma
  – Bronchitis
• Airway collapse
  – Emphysema
  – Bronchiectasis

Upper airway – large airways
• Trachea/mainstem bronchi: tumor, stenosis, collapse
• Pharynx: tumor, infection, edema, foreign body

Adapted: WM Gold, 1994
Obstructive defects (lower/peripheral airways)

**Spirometry**

<table>
<thead>
<tr>
<th></th>
<th>Ref Meas</th>
<th>Pre Meas</th>
<th>% Ref</th>
<th>CI</th>
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<td>FEV1/FVC%</td>
<td>76</td>
<td><strong>46</strong></td>
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<tr>
<td>FEV1/SVC%</td>
<td>76</td>
<td><strong>39</strong></td>
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<tr>
<td>Vol Extrapolated Liters</td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- FVC normal or low
- FEV1 low (sometime normal)
- FEV1/FVC low
- Midflows low
“Midflows”

- Mean expiratory flow rate at 25-75% FVC (MEFR\textsubscript{25-75%})
- Forced expiratory flow rate at 25-27% (FEF\textsubscript{25%-75%})
  - (the average expiratory flow over the middle half of the FVC)

- Highly dependent on the validity of the FVC measurement and the level of expiratory effort.
- When the FEV1 and FEV1/VC are in the normal range, the wide variability of the midflows in healthy subjects must be considered
- Helpful in the presence of a borderline FEV1/FVC

“...abnormalities in these mid-range flow measurements during a forced exhalation are not specific for small airway disease in individual patients.”

Eur Respir J 2005; 26: 948–968
FEF$_{25-75}$ % predicted was well correlated with bronchodilator responsiveness in asthmatic children with normal FEV$_1$ values. FEF$_{25-75}$ % predicted should be evaluated in clinical studies of asthma in children, and may be of use in predicting the presence of clinically relevant reversible airflow obstruction.

“...childhood asthmatics with a normal FEV1, FEF25–75 should be considered as a potentially important spirometric variable that can be used as a marker of BDR, asthma severity, and asthma exacerbations both in the clinical and research settings.”

Forced expiratory flow between 25 and 75 percent of vital capacity (FEF25-75) less than 65 percent correlates with reversible airflow obstruction in children with normal FEV$_1$ and may be a useful measure in this subgroup, although further studies are needed ...
Other flow measures — The transition from normal function to moderate airflow obstruction is generally gradual. Physiologists have searched for a test that is more sensitive than the FEV₁ for detection of airflow obstruction in its early stages. None has proven to be as reliable as the index obtained by dividing the FEV₁ by the FVC. The forced expiratory flow between 25 and 75 percent of the FVC (also known as FEF25-75 or maximal mid-expiratory flow rate) should not be used to detect "small airways disease" in adults, due to poor reproducibility [13].
Asthma:

- Recurring and variable symptoms
- Airflow limitation with reduced FEV1/FVC
- Positive bronchodilator reversibility test
- Positive bronchial challenge test (bronchial hyperresponsiveness)

Bronchodilator reversibility

- Salbutamol 100 ug X 4 (or Ipratropium)
- 15 minutes
- Increase FEV1 or FVC of 200 ml and \( \geq 12\% \)
Obstructive ventilatory defect with moderately severe reduction in FEV1, with significant increases in, and normalization of, FVC and FEV1 after administration of bronchodilators

- Increase FEV1 or FVC of 200 ml and $>12\%$
An increase in FEV₁ and/or FVC ≥12% of control and ≥200 mL constitutes a positive bronchodilator response.

In the absence of a significant increase in FEV₁ and/or FVC, an improvement in lung function parameters within the tidal breathing range, such as increased partial flows and decrease of lung hyperinflation, may explain a decrease in dyspnoea.

The lack of a bronchodilator response in the laboratory does not preclude a clinical response to bronchodilator therapy.

FEV₁: forced expiratory volume in one second; FVC: forced vital capacity.
Reversible with bronchodilator?

<table>
<thead>
<tr>
<th>Spirometry</th>
<th>Ref</th>
<th>Pre Meas</th>
<th>Pre % Ref</th>
<th>CI</th>
<th>Post Meas</th>
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Methacholine Challenge Testing: Bronchial Hyperresponsiveness - Indications

• Diagnosis of Asthma when:
  o Traditional methods, i.e. spirometry with pre and post BD have not been diagnostic
    – Strong clinical suspicion

• Symptoms of cough, wheeze, chest tightness
  o Exposure to cold air
  o Exercise
  o Exposure to allergens
  o Workplace exposure
  o Respiratory viral infections
Bronchoprovocation: Methacholine Challenge (five breath dosimeter protocol)

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</table>
Bronchoprovocation: Methacholine Challenge

PC 20 FEV1:

Baseline 0.0625 0.25 1.0 4.0 16.0 Post

120
110
100
90
80
70
60
50
40
30
20
10
0
### Bronchoprovocation: Methacholine Challenge (five breath dosimeter) protocol

<table>
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<table>
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</thead>
<tbody>
<tr>
<td><strong>FEF25-75%</strong></td>
<td>2.62</td>
<td>1.29</td>
<td>1.41</td>
<td>1.28</td>
<td><strong>0.52</strong></td>
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<td></td>
<td><strong>0.88</strong></td>
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<tr>
<td>%Ref</td>
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<td>54</td>
<td>49</td>
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<td><strong>33</strong></td>
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<tr>
<td>%Change</td>
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<td>-1</td>
<td>-60</td>
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Bronchoprovocation: Methacholine Challenge

PC 20 FEV1: 0.461
### TABLE 5

**CATEGORIZATION OF BRONCHIAL RESPONSIVENESS**

<table>
<thead>
<tr>
<th>PC_{20} (mg/ml)</th>
<th>Interpretation*</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 16</td>
<td>Normal bronchial responsiveness</td>
</tr>
<tr>
<td>4.0-16</td>
<td>Borderline BHR</td>
</tr>
<tr>
<td>1.0-4.0</td>
<td>Mild BHR (positive test)</td>
</tr>
<tr>
<td>&lt; 1.0</td>
<td>Moderate to severe BHR</td>
</tr>
</tbody>
</table>

Before applying this interpretation scheme, the following must be true: (1) baseline airway obstruction is absent; (2) spirometry quality is good; (3) there is substantial postchallenge FEV₁ recovery.

### TABLE 5-5 Criteria for Rating Permanent Impairment due to Asthma

#### Asthma

<table>
<thead>
<tr>
<th>CLASS</th>
<th>CLASS 0</th>
<th>CLASS 1</th>
<th>CLASS 2</th>
<th>CLASS 3</th>
<th>CLASS 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHOLE PERSON IMPAIRMENT RATING (%)</td>
<td>0</td>
<td>2%-10%</td>
<td>11%-23%</td>
<td>24%-40%</td>
<td>45%-65%</td>
</tr>
<tr>
<td>SEVERITY GRADE (%)</td>
<td>2 4 6 8 10 A B C D E (Minimal)</td>
<td>11 14 17 20 23 A B C D E (Mild)</td>
<td>24 28 32 36 40 A B C D E (Moderate)</td>
<td>45 50 55 60 65 A B C D E (Severe)</td>
<td></td>
</tr>
<tr>
<td>CLINICAL PARAMETERS (MINIMUM MEDICATION NEED, FREQUENCY OF ATTACKS, ETC)</td>
<td>No medication required</td>
<td>Occasional bronchodilator use (not daily use) (&lt;500 mcg per day of beclomethasone or equivalent)</td>
<td>Daily low-dose inhaled steroid</td>
<td>Daily medium or high-dose (500 to 1000 mcg per day) inhaled steroid and/or short periods of systemic steroids and a long acting bronchodilator</td>
<td>Daily use of steroids, systemic and inhaled, and daily use of maximum bronchodilators</td>
</tr>
<tr>
<td>MAXIMUM POSTBRONCHODILATOR FEV1 (%)</td>
<td>&gt;80%</td>
<td>70%-80%</td>
<td>60%-69%</td>
<td>50%-59%</td>
<td>&lt;50%</td>
</tr>
</tbody>
</table>

#### OBJECTIVE TESTS FOR DEGREE OF AIRWAY HYPERRESPONSIVENESS

<table>
<thead>
<tr>
<th>PC&lt;sub&gt;20&lt;/sub&gt; mg/mL&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Minimal</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
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</thead>
<tbody>
<tr>
<td>&gt;8</td>
<td>3-5</td>
<td>3-&gt;0.5</td>
<td>0.5-0.25</td>
<td>0.24-0.125</td>
</tr>
</tbody>
</table>

---

<sup>b</sup> Postbronchodilator FEV<sub>1</sub>, percentage predicted is class of airway hyperresponsiveness.

<sup>c</sup> Percent predicted FEV<sub>1</sub>, after albuterol therapy.
<table>
<thead>
<tr>
<th>Spirometry</th>
<th>Ref</th>
<th>Pre Meas</th>
<th>Pre % Ref</th>
<th>CI</th>
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</thead>
<tbody>
<tr>
<td>FVC</td>
<td>3.07</td>
<td>2.54</td>
<td>83</td>
<td>0.78</td>
</tr>
<tr>
<td>FEV1</td>
<td>2.43</td>
<td>2.04</td>
<td>84</td>
<td>0.66</td>
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<tr>
<td>FEV1/FVC</td>
<td>80</td>
<td>80</td>
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<td>11</td>
</tr>
<tr>
<td>FEV1/SVC</td>
<td>80</td>
<td>79</td>
<td>79</td>
<td>11</td>
</tr>
<tr>
<td>FEF25-75%</td>
<td>2.40</td>
<td>2.18</td>
<td>91</td>
<td>1.50</td>
</tr>
<tr>
<td>PEF</td>
<td>6.29</td>
<td>6.95</td>
<td>111</td>
<td>2.19</td>
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<td>FEF/FIF50</td>
<td>0.65</td>
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<td></td>
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<tr>
<td>FET100%</td>
<td></td>
<td>7.14</td>
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</tr>
<tr>
<td>Vol Extrap</td>
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<tr>
<td>FVL ECode</td>
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</tbody>
</table>
Derivation of Predicted Values

• Large numbers of measurements in an asymptomatic, nonsmoking population
• Development of regression equations
  o spirometry
  o lung Volumes
  o DLCO
  o VO$_2$max
• Populations change over time
  o cohort effect (changes of the population)
  o health of the society (nutrition, survival of less healthy infants, etc)
Spirometry Reference Sets/Equations

- Morris 1971
- Knudson 1976 (predicted values mandated by the Cotton Dust Standard)
- Crapo 1981
- Knudson 1983
- Miller 1986
- Hankinson et al. 1999 (NHANES III)
- ATS/ERS 2005
  - NHANES III
  - ERS 1993 – European Community for Steel and Coal
- Global Lung Initiative (GLI)
National Health and Nutrition Examination Survey (NHANES III)

Spirometric Reference Values from a Sample of the General U.S. Population

JOHN L. HANKINSON, JOHN R. ODENCRANTZ, and KATHLEEN B. FEDAN

Division of Respiratory Disease Studies, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Morgantown, West Virginia

• Data collected 1988-1994
• 81 counties across U.S.
• Spirometry on 20,627 participants ≥ 8 y.o.
• Caucasian-Americans, African-American and Mexican-American
• Use of equipment and procedures meeting ATS standards
Use of Reference (predicted) Values

- Predicted values should be obtained from studies of “normal” or “healthy” subjects with the same anthropometric (e.g. sex, age and height) and ethnic characteristics of the patient being tested.
- Height and weight should be measured for each patient at the time of testing.
- When using a set of reference equations, extrapolation beyond the size and age of the investigated subjects should be avoided.

Also:
- Mixed race – use the race the patient most closely identifies with (but consider in the interpretation).
- Asian – Americans correction factor of 0.88 (Hankinson, 2010).

Eur Respir J 2005;26:948-968
Multi-ethnic reference values for spirometry for the 3–95-yr age range: the global lung function 2012 equations


### TABLE 2

<table>
<thead>
<tr>
<th>Group</th>
<th>Males</th>
<th>Females</th>
<th>Total</th>
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</thead>
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<tr>
<td></td>
<td>N</td>
<td>Age range yrs</td>
<td>N</td>
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<tr>
<td>Caucasian</td>
<td>25827</td>
<td>2.5–95</td>
<td>31568</td>
</tr>
<tr>
<td>African–American</td>
<td>1520</td>
<td>6–85</td>
<td>2025</td>
</tr>
<tr>
<td>North East Asian</td>
<td>1414</td>
<td>16–91</td>
<td>3578</td>
</tr>
<tr>
<td>South East Asian</td>
<td>3095</td>
<td>3.3–86</td>
<td>5160</td>
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<tr>
<td>Total</td>
<td>31856</td>
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<td>42331</td>
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</table>

*: the countries of origin are listed in table E1 in the online supplementary data.
"For each lung function index, values below the 5th percentile of the frequency distribution of values measured in the reference population are considered to be below the expected ‘normal range’"

(appplies to FEV1, FVC, FEV1/FVC, FEF 25-75)
Obstruction: FEV1/FVC < 70%
Fixed cut-off controversial

“The practice of using 0.70 as a lower limit of the FEV1/FVC ratio results in a significant number of false positive results in males aged > 40 yrs and females > 50 yrs, as well as in a risk of overdiagnosis of chronic obstructive pulmonary diseases (COPD) in asymptomatic elderly neversmokers.”

Eur Respir J 2005;26:948-968
Severity: characterized by the FEV1 (not FEV1/FVC)

<table>
<thead>
<tr>
<th>Degree of severity</th>
<th>FEV1 % pred</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>

Eur Respir J 2005; 26: 948–968
Obstructive defect, moderately severe reduction in FEV1

<table>
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<tr>
<th>Spirometry</th>
<th>Ref</th>
<th>Pre Meas</th>
<th>Pre % Ref</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC Liters</td>
<td>2.76</td>
<td>** 1.81</td>
<td>** 65</td>
<td>0.69</td>
</tr>
<tr>
<td>FEV1 Liters</td>
<td>2.21</td>
<td>** 1.19</td>
<td>** 54</td>
<td>0.59</td>
</tr>
<tr>
<td>FEV1/FVC %</td>
<td>81</td>
<td>** 66</td>
<td>** 25</td>
<td>11</td>
</tr>
<tr>
<td>FEF25-75% L/sec</td>
<td>2.34</td>
<td>** 0.59</td>
<td>** 75</td>
<td>1.33</td>
</tr>
<tr>
<td>PEF L/sec</td>
<td>5.98</td>
<td>4.47</td>
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<td>1.94</td>
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<tr>
<td>FEF/FIF50</td>
<td>0.31</td>
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<tr>
<td>FET100% Sec</td>
<td>8.73</td>
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<tr>
<td>Vol Extrapolated Liters</td>
<td>0.02</td>
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</table>
Severity: characterized by the FEV1 (not TLC or FEV1/FVC)

<table>
<thead>
<tr>
<th>Degree of severity</th>
<th>FEV1 % pred</th>
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<tbody>
<tr>
<td>Mild</td>
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</tr>
<tr>
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<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>
Obstructive defect present, but FEV1 is normal

<table>
<thead>
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<th>Ref</th>
<th>Pre</th>
<th>Pre</th>
<th>Cl</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC</td>
<td>3.51</td>
<td>3.58</td>
<td>102</td>
<td>0.65</td>
</tr>
<tr>
<td>FEV1</td>
<td>2.98</td>
<td>2.57</td>
<td>86</td>
<td>0.55</td>
</tr>
<tr>
<td>FEV1/FVC %</td>
<td>84</td>
<td><strong>72</strong></td>
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<tr>
<td>FEF25-75% L/sec</td>
<td>3.34</td>
<td><strong>1.79</strong></td>
<td><strong>54</strong></td>
<td>1.15</td>
</tr>
<tr>
<td>PEF</td>
<td>6.67</td>
<td>6.53</td>
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<td>1.60</td>
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<tr>
<td>FEF/FIF50</td>
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<td></td>
</tr>
<tr>
<td>FET100% Sec</td>
<td>8.60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vol Extrapol Liters</td>
<td>0.10</td>
<td></td>
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</tbody>
</table>
Do not beat a dead horse.

No ACTUAL animals were harmed in the making of this cartoon.
Summary

• Spirometry is used for
  – screening and surveillance in evaluation of individuals exposed to toxic inhalants,
  – evaluation of respiratory impairment,
  – Monitoring therapeutic effect/disease progression
  – Diagnosing obstructive lung disease
  – Suggesting restrictive lung disease

• Spirometry is essential in the diagnostic evaluation of patients with suspected airways disease

• Even small changes in the size of airways have very large effects on the flow of air in the lungs (Poiseuille)

• To be useful diagnostically, spirometry must be valid (3 acceptable, 2 repeatable trials)

• Midflows (FEF 25-75) not helpful in adults, but useful in children
END

Soli Deo Gloria