Office assessment of pulmonary function

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Much can be done in the physician's office to assess pulmonary function from history, physical examination, and spirometry. We will focus attention on spirometry, office spirometry being only an extension of the history and physical examination. Experiences and results obtained with a new device available for office spirometry will be reported.

History

The history relating to the pulmonary system must be thorough, detailed, and specific. The complaints of the patient should be listed in the patient's own words, for example, "I have no wind," with an estimation of the duration, progress, and aggravating factors. The symptom of shortness of breath is most important. It is necessary to relate it to activity and exercise tolerance with an attempt at grading the severity of dyspnea.[1] The patient should be observed while he or she is dressing, walking, or moving about in the examination facility to provide a useful estimate of severity of the dyspnea. Other pulmonary symptoms such as coughing, sputum production, and wheezing are indicative of the presence of disease and probably impairment of pulmonary function, but they do not of themselves characterize the type of impairment or its severity. Only with spirometry can this be accomplished.

Physical examination

Abnormal physical findings frequently indicate advanced pulmonary impairment, as manifested by cyanosis, clubbed digits, peripheral edema, and plethora. On examination of the chest, attention should be focused on the character and rate of breathing, the use of accessory muscles of breathing, pursed lip breathing, coughing, audible wheezing, and the configuration of the thorax. On chest percussion, a hyperresonant note frequently denotes lung hyperinflation. The level of the diaphragm should be determined on both inspiration and forced expiration to determine the extent of diaphragmatic movement. Auscultation should be performed both during quiet and on forced breathing. The latter may bring out expiratory obstruction, trapping, and rhonchi otherwise not detectable during quiet breathing. Physical findings indicate abnormality, but do not quantitate or characterize the abnormality.

Spirometry

The most important fundamental measurement of lung function is spirometry. It is useful in early detection of disease and in assessment of the severity of the disease.[2] Spirometry provides an objective appraisal of respiratory symptoms and signs. It is useful in determining the response to therapy in asthma, sarcoidosis, interstitial pneumonitis, and other diseases. It has prognostic value. Spirometry is simple to perform, not expensive, and can be done effectively as an office procedure. The application of spirometry is broad. It should be a part of every physical examination and preoperative appraisal. Although spirometry requires cooperation of the patient, it can be repetitively performed and is highly reproducible. Measurements can be taken of the vital capacity (VC), forced vital capacity (FVC), and forced expiratory volume in one second (FEV_1). The ratio of the FEV_1 to the FVC and the forced expiratory flow in the middle half of the forced vital capacity ($FEF_{25\%-75\%}$) are most useful[3] (*Fig. 1*).

The American Thoracic Society and the American College of Chest Physicians have issued statements referable to the standardization of spirometers.[4, 5] In essence, an office spirometer should be practical, reliable, and include a graphic tracing of the expiratory flow pattern. It should be reasonably priced, simple to operate, and capable of measuring the parameters listed in the previous paragraph. Its minimum capacity should be a volume of 7 liters and have a recording time of at least 6 seconds and preferably 10. It should be accurate and compare favorably with standard laboratory techniques using water-sealed or syringe systems.

The classic water-sealed spirometers of the past are not practical for office use. More simplified portable and desk top spirometers are available for this purpose. Electronic spirometers are fre-

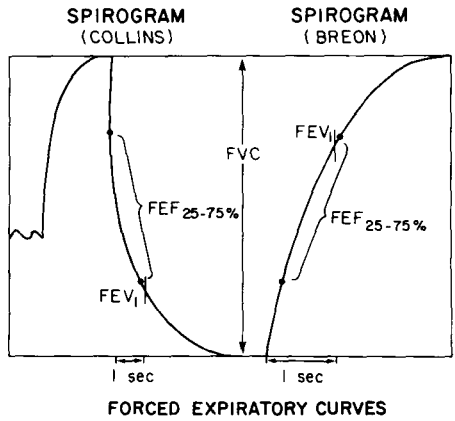


Fig. 1. Expiratory flow curves. Two methods of display with important parameters depicted. The water-sealed spirometer versus the bellows.

quently unreliable, require constant calibration, and are impractical for office use.

Interpretation of the spirogram

Spirometric values are compared with predicted normal values based on sex, age and height, and are expressed as a percentage of the predicted normal. Although race and color are not currently included in the prediction formulas, they should be. Recent studies have shown a deviation from the predicted normal in blacks and American Indians to be as much as 16% lower.[6] Regardless of racial deviations, there is a wide range of normal variability, making formulas somewhat inaccurate. The reproducibility of the spirogram is good. For example, normal predicted values have a range of ±20%, whereas reproducibility is within ±5%.

The VC is reduced because of chest-wall, neuromuscular, diaphragmatic, or parenchymal disease. This reduction may be due to a direct loss of lung volume or to a pseudorestriction secondary to obstructive lung disease as occurs with bullae and lung hyperinflation. Occasionally, the restriction may be caused by inability of the subject to perform the maneuver to completion. The VC is performed first slowly, allowing the individual adequate time for completion of exhalation. Then, it is done forcibly and rapidly with considerable effort in an attempt to expel the volume in as short a time as possible. Any difference between the slow VC and FVC is attributable to air trapping, as a result of sudden airway collapse or obstruction to airflow. The FVC is a volume measurement. However, it can also be used to determine the flow rates, the most important of which is the FEV_1. The FEV_1 can be expressed as an absolute value related to the predicted normal or as a ratio of the FVC. The FEV_1 can be reduced in obstructive as well as in restrictive abnormalities. The FEV_1 to FVC ratio is most useful in determining whether an obstructive or restrictive pattern is present. A low ratio indicates obstruction; a high ratio indicates restriction. The normal FEV_1 to FVC ratio is 75% to 83%.

The forced expiratory flow of the middle half of the forced vital capacity ($FEF_{25\%-75\%}$) is a sensitive parameter in detecting early airways obstruction. It depends upon effort as well as on elastic recoil of the lungs. It correlates well with small airways function if no major airways obstruction exists. Because of a wide range of normal variability and frequent presence of major airways obstruction, the $FEF_{25\%-75\%}$ is not a useful expression of severity of abnormality.

Reversibility of airways obstruction can be determined by administering an aerosol bronchodilator, such as isoproterenol, with spirometry performed before and after. Improvement in the FVC and/or the FEV_1 or the $FEF_{25\%-75\%}$ greater than 10% indicates reversible bronchospasm. The procedure can be done quickly and effectively in the office by having the subject inhale the bronchodilator via a metered dose mist dispenser. The compressor nebulizer unit can also be employed; however, this procedure becomes more complex and takes more time with only a slightly greater yield. It is more a laboratory than an office procedure.

It becomes apparent that spirometry permits division of patterns into three types: (1) obstruction to airflow, (2) restriction of volume, and (3) combined obstruction and restriction.

An obstructive pattern is characterized by a normal or near normal FVC with a decreased FEV_1 and a low FEV_1 to FVC ratio. Obstruction produces

large lungs that empty slowly, commonly seen in asthma, bronchitis, and emphysema. Reversibility of obstruction is characteristic of asthma, whereas bronchitis and emphysema usually do not have a reversible component.

A restrictive pattern is characterized by a decreased VC, a proportionally decreased FEV_1, and a normal FEV_1 to FVC ratio. Restricted lungs are small and empty rapidly. Fibrosis, neuromuscular disease, and extrapulmonic compression are examples of diseases producing a restrictive pattern.

A combined restrictive and obstructive pattern is depicted by a reduction in the FVC, FEV_1, and flow rates, in addition to a low FEV_1 to FVC ratio.

Prognostically, spirometry is very useful.[7] Patients with a VC below 1500 cc or a FEV_1 below 1 liter are severely impaired and dyspneic at rest. Normally there is a decrease of approximately 30 cc of FEV_1 per year due to aging; however, in severe chronic obstructive disease the rate of loss is greater (50 to 80 cc/yr). The FVC rate of loss in disease is variable and unpredictable. The FEV_1 to FVC ratio is also an unreliable index of disease progression. In disease progression it seems preferable to look at the absolute values rather than the ratio. The ratio is used to characterize the pattern as an obstructive or restrictive type.

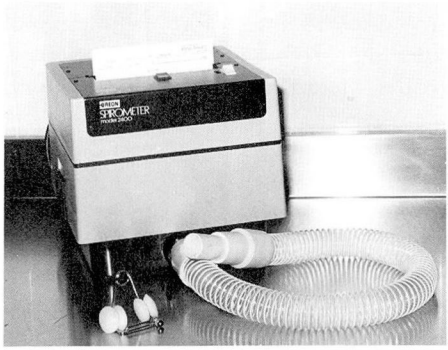


Fig. 2. The Breon model 2400 spirometer, a compact, portable reliable unit suitable for office use.

Experience with a new office spirometer

With the use of mechanical models and human subjects, a comparison was made between Breon model 2400 spirometer, a positive displacement direct reading portable unit, and the standard 13.5-liter water-sealed Collins spirometer for accuracy, precision, and reliability. The Breon, a compact desk-top instrument (*Fig. 2*) provides a permanent record of lung function. It produces a tracing of the expired volume as a function of time. It operates from a conventional electrical outlet and has automatic activation of the horizontal pen movement with timing. The chart moves upward in proportion to the volume displaced by the internal rolling diaphragm. The time base can be set for 6 or 12 seconds to insure measurement of the total exhalation. Volumes are read directly from the chart at either ATPS or assumed BTPS. The instrument was checked for volume, range, calibration, activation volume, back pressure, and leakage. Normal subjects and patients with abnormal lung function were tested to give a wide range of values for the VC, FVC, FEV_1, and $FEF_{25\%-75\%}$. Sixty subjects participated

Table. Regression equations (x on y) and correlation coefficients (r)

Normal subjects, 30 (Breon vs Collins)		
FVC	$x = 0.98y - 0.07$	$r = 0.99$
FEV_1	$x = 0.926 + 0.13$	$r = 0.98$
$FEF_{25\%-75\%}$	$x = 0.69y + 1.11$	$r = 0.91$
Patients, 30 (Breon vs Collins)		
FVC	$x = 1.00y - 0.11$	$r = 0.97$
FEV_1	$x = 0.99y - 0.02$	$r = 0.96$
$FEF_{25\%-75\%}$	$x = 0.94y - 0.10$	$r = 0.91$
(Phantom volume $r = 0.9976$)	$x = 0.9859y + 0.0150$	

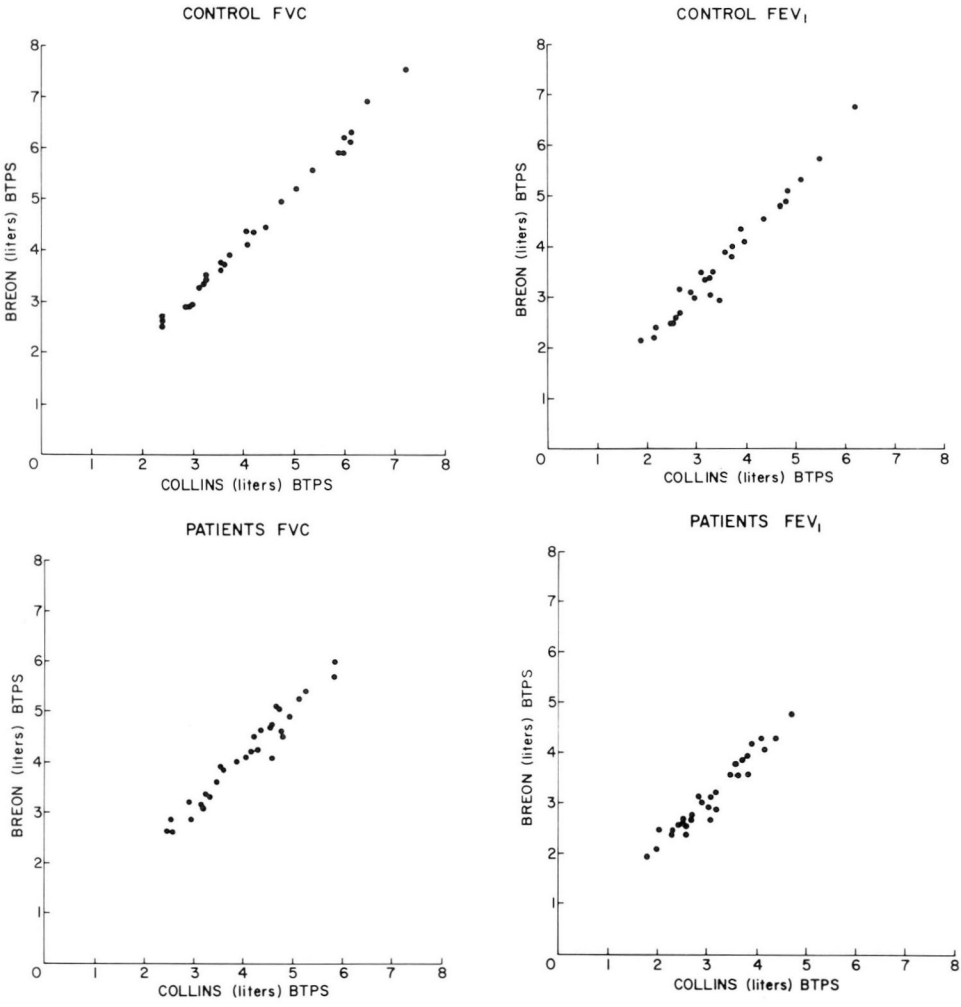


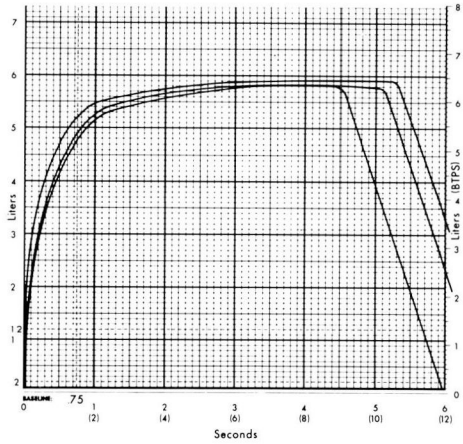
Fig. 3A–D. Plots showing comparison of the Breon with the Collins for FVC, FEV_1 in normal (control) and patients.

in the study: 30 normals, 30 patients. Spirometry was performed with both units. The subjects were randomly assigned to one or the other device. They were tested in the sitting position with nose clip applied. Measurements were performed with adherence to strict standard protocol. A minimum of six tracings were taken on each spirometer per patient. Volumes were reproduced within 5% of each other. The best values were taken from the same curve, recorded, and corrected from ATPS to BTPS.

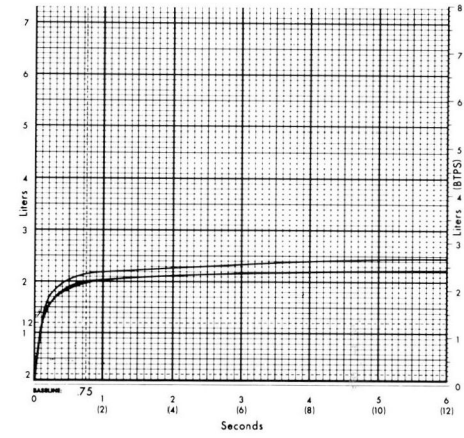
Results

Calibration with known volumes and flows was found to be accurate and linear within practical limits, with a good coefficient of correlation ($r = 0.9$). The Breon spirometer weighs less than 4.5 kg (10 pounds) and is 29.2 x 25.4 cm (11½ x 10 inches). As much as 180 cc was necessary to activate the recording

NORMAL

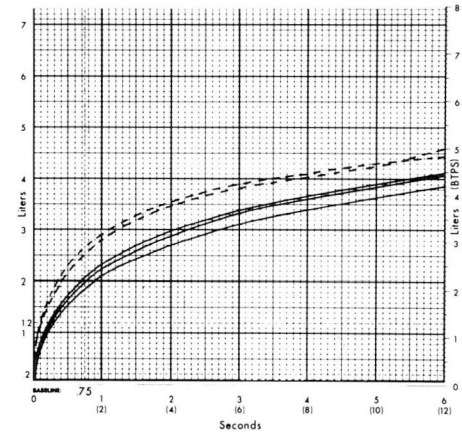


RESTRICTIVE



Figs. 4–6. Characteristic spirographic patterns: normal, restrictive, and obstructive. Note the high degree of reproducibility. In *Figure 6* the hashed lines represent the improvement following bronchodilator inhalation.

OBSTRUCTIVE
(Pre & Post B.D.'s)



pen along the horizontal axis. This volume, however, was being recorded vertically. Therefore, back extrapolation easily corrected for any possible mechanical error. Clinically this was not thought to be significant. Back pressure to airflow at the mouthpiece of the Breon was 1 to 2 cm of H_2O compared to 4 cm of H_2O in the Collins unit. There appeared to be no leakage when pressure was applied to the Breon. Results of the studies of the normal subjects and patients showed a high degree of correlation between both spirometers.

The correlation coefficients and the regression formulas comparing the Breon with the Collins are shown in the *Table*. From the regression equations, for example, an FVC of 4 liters on the Breon would yield a value of 3.99 liters on the Collins. Comparison plots are shown in *Figure 3A–D*.

While operating both spirometers, it became apparent that the Breon was easier to handle. The recording paper was simply slipped into the unit and the pen adjusted. The device was automatically activated by the patient's exhalation. Speed was adjusted to 2.5 or 1.25 cm per second to record either slowly or rapidly.

The Breon spirometer is an accurate device for assessing ventilatory function routinely as shown by its performance in comparison with the Collins. Its ease of use and its durability make it suitable

for office practice, outpatient clinic, bedside, and fieldwork. *Figures 4–6* show normal restrictive and obstructive patterns as obtained on the Breon.

Summary

Much information about pulmonary function can be obtained in the office by history, physical examination, and spirometry. Office spirometry is easy to do and the equipment is readily available and practical. Spirometry is useful in the early detection of disease, in ascertaining the severity of disease, in prognosis, and following the course of disease and the response to therapy. Parameters obtained with spirometry are the VC, FVC, FEV_1, and $FEF_{25\%-75\%}$. Of these, the FEV_1 is the most useful clinically. Spirometry allows diagnostic differentiation of disease into obstructive, restrictive, or combined patterns. The Breon spirometer was tested and compared with the Collins using mechanical laboratory techniques, normal subjects, and patients with impaired lung function. The correlation was excellent. The results of the tests proved that the unit is ideal for office practice.

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