

Benefits of and barriers to the widespread use of spirometry

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Purpose of review

To review the basis for spirometry, its benefits in diagnosing and managing both acute and chronic pulmonary disorders with emphasis on chronic obstructive pulmonary disease, and to critically examine the barriers to its widespread use.

Recent findings

A number of recent articles have established the scientific basis for spirometry in the early identification of chronic obstructive pulmonary disease and in improving smoking cessation in patients with chronic obstructive pulmonary disease. Economic and other considerations are reported.

Summary

Spirometry is an important office diagnostic device that should be used by all primary care and most specialist physicians. Spirometry is to dyspnea as the electrocardiogram is to chest pain.

Keywords

COPD, dyspnea, economics, smoking cessation, spirometry

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Abbreviations

COPD	chronic obstructive pulmonary disease
FEF	forced expiratory flow
FEV₁	forced expiratory volume in 1 second
FVC	forced vital capacity

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Introduction

The spirometer should be one of the most useful instruments for office practice. No primary care physician or pulmonary or cardiac specialist can practice medicine without the availability of office spirometry. Today the modern spirometer must find its rightful place alongside the sphygmomanometer and the electrocardiograph. Abnormal spirometry is an indicator of increased risk for premature death from all causes. This fact has been known since the time of its invention in 1846 by John Hutchinson, a surgeon, and the coining of the term "vital capacity" [1]. Spirometry has a wide application throughout general medicine and pulmonology.

Background

Why has spirometry been so slow to be accepted in the mainstream of clinical practice? Why is it not commonly used in the identification of early stages of chronic obstructive pulmonary disease (COPD)? I believe that spirometry has been a victim of too much mystique. It has also been necessary to conduct careful studies of the structure—function relationships of the human lung to understand what causes alterations in spirometric measurements. Longitudinal human studies have helped clarify the clinical significance of tests purported to indicate early stages of COPD. Also, in the past, inexpensive and user-friendly devices have not been available for office and clinic use. All of this is now changing rapidly. Today the primary care physician or specialist and his or her assistant can learn the basics of spirometry easily, which provides for two main values: the forced vital capacity (FVC) and the forced expiratory volume in 1 second (FEV₁), and the FEV₁/FVC%.

Spirometry simply measures airflow out of fully inflated lungs. In a full inspiration the lungs are filled by muscular force, to expand the lungs and thorax. Full inhalation stretches the chest to its maximum and the lungs expand passively. After this, a full forced expiration rapidly empties the lungs into a device that records flow over time. Normal lungs empty in at least 6 seconds.

Expiratory airflow is a function of muscular effort, elastic recoil of lungs and thorax, small airways function, large airways function, and interdependence between small airway and the surrounding alveolar attachments.

Tests of small airways disease

After the classic description of small airways disease in smokers by Hogg and associates [2], an understandable focus on possible physiologic markers of small airway inflammation, fibrosis, and mucous plugging emerged. At one time, the most popular spirometric index for small airways pathology was purported to be the forced expiratory flow between 25% and 50% of the FVC ($FEF_{25\%-75\%}$) [3]. Additional tests of small airways pathology were the nitrogen washout test for closing volume [4], and flow-volume tests using gases of different densities [5] and frequency dependency tests [6]. Although abnormalities in the $FEF_{25\%-75\%}$ did correlate with small airways lesions as determined by surgical specimens, the relation was not significantly better than a reduction in FEV_1/FVC [3].

Nitrogen washout tests are not suitable for widespread application, such as in office practice. Of greater significance is the fact that longitudinal tests of patients with an abnormal closing volume, as determined by nitrogen washout and other tests of focal expiratory flow, did not predict a later reduction in FEV_1 or the emergence into clinically significant disease [7,8].

The following paragraphs list and explain the benefits of spirometry.

Spirometry is an important database

Normal spirometry predicts a high likelihood of long-time survival; abnormal spirometry indicates an adverse prognosis. Simple spirometric measures provide an important database for the primary care physician and specialist. One example is the patient who comes to the physician with cough and dyspnea thought to be associated with a certain occupation. Knowledge of prior spirometry will give a baseline for comparison.

Spirometry is key to diagnosis and patient monitoring

Simple office spirometry is key to the identification of many disease states and to the objective monitoring of responses to therapy for these heterogeneous conditions. It should play a central role any time a physician prescribes potent bronchoactive and antiinflammatory drugs. A clinician would not treat hypertension without measurements of blood pressure, give insulin or an oral hypoglycemic agent to a diabetic without measurements of blood sugar, treat cardiac arrhythmias without electrocardiogram monitoring, or use warfarin anticoagulation without monitoring prothrombin times and international normalized ratio. Nonetheless, spirometry is still not part of the primary care practice of most physicians who regularly prescribe drugs designed to improve airflow, volume, or both.

Spirometry is crucial in the detection of acute and chronic airflow obstruction and in the monitoring of responses to

therapy and disease progress. Spirometry can distinguish asthma from COPD on the basis of objective improvement in airflow, after use of bronchodilators, and, when indicated, corticosteroids.

Spirometry is also key to the diagnosis and management of all of the restrictive pulmonary diseases. As the life insurance industry knows, spirometry is an indicator of all-cause mortality!

Spirometry in chronic obstructive pulmonary disease

By far, the greatest risk factor in the development of emphysema, asthma, and chronic bronchitis—that is, the full spectrum of COPD—is smoking. In early COPD, FEV_1 begins to decrease before the FVC. This decrease results in a reduced ratio between FEV_1 and FVC (less than the normal 70%). Population studies have shown clearly that this single value (FEV_1/FVC) can identify patients who are at risk for undergoing accelerated lung function loss. Abnormalities in FEV_1 and FEV_1/FVC herald the onset of clinically significant COPD [9].

Spirometry determines lung age

Another way to look at the effect of smoking on lung function is the concept of lung age [10], which is computed by matching an individual's FEV_1 value with the age at which that FEV_1 value is considered normal based on predicted values. If a 6-foot, 47-year-old man has an FEV_1 of 2.2, for example, his lung age is 72, because 2.2 is the FEV_1 measurement considered normal for a 72-year-old man of that height. Calculating a patient's lung age can be a motivator in smoking cessation [10].

Spirometry is an aid in smoking cessation

Because of the powerful correlations between spirometric abnormalities and smoking-related diseases, it follows that smoking cessation should be the key intervention whenever spirometric abnormalities are found in a smoker.

The course and prognosis of COPD are improved greatly in patients who stop smoking. In a study conducted in the United Kingdom, patients who stopped smoking at age 45 and whose FEV_1 was 70% of that predicted at age 25 had a decrease in deterioration of lung function within a few years, so that their lung-function loss paralleled the normal age-related change, or approximately 30 mL/y for a normal-size man [11]. Even patients who stopped smoking at age 65 and whose FEV_1 was reduced to 30% of that predicted at age 25 had improved survival compared with individuals who continued to smoke. The message of this study is that it is never too late to stop smoking, although it is better if patients stop smoking earlier in the natural course of COPD.

The 1994 Lung Health Study also showed a reduced rate of decline in FEV_1 over 5 years in patients who stopped smoking. Those with the mildest abnormalities had a slight improvement in airflow before the mild, age-related decline occurred [12]. It is highly noteworthy that the most common cause of death in the middle-aged participants in the Lung Health Study was lung cancer, with an incidence much higher than heart attack and stroke. This finding is remarkable since these patients' average age was 48.5 years [12].

The National Lung Health Education Program

The National Lung Health Education Program (NLHEP) is a national health care initiative aimed at the early diagnosis of COPD and related disorders [13]. The Spirometer Committee of the NLHEP recommends spirometry in all smokers older than the age of 45 years and in anyone with cough, mucous hypersecretion, dyspnea, or wheeze [14]. Because the forced expiratory volume in 6 seconds (FEV_6) can be taken as a surrogate for the FVC, new office-based devices use the FEV_6 in the denominator of the FEV_1/FVC equation [15]. This use is because an FEV_1/FEV_6 of less than 70% is as good a predictor of a rapid decline in FEV_1 as the full ratio. Because it is difficult for many patients to exhale for 12 to 15 seconds to complete the full expiratory maneuver, it is practical and reasonable to limit the forced expiratory airflow measurement to 6 seconds.

A new family of spirometers has been developed in direct response to the NLHEP initiative. Many of these devices sell for \$1000 or less. They can store up to 300 tests. They can be interfaced with a printer to record time-volume curves or flow-volume curves [16].

If the vital capacity is so important to clinical medicine, why don't all physicians have spirometers in their offices just as they have the chest radiograph (introduced into medicine in 1895), the sphygmomanometer (invented in 1896), or an ECG machine (invented in 1903)? Could it be that pulmonologists and physiologists who established pulmonary function laboratories clouded their instrument in mystery, so as to obscure the true value of spirometry in primary care medicine? If so, "we have found the enemy, and he is us!" (borrowed from the comic strip, Pogo).

There is absolutely nothing that is complicated about spirometry. Spirometry measures airflow from fully inflated lungs over time in liters, as described by Hutchinson. Tiffeneau added a second measurement, the FEV_1 , working at the Hotel Dieu in Paris in 1947. Thus, the FVC is the amount of air exhaled from fully inflated lungs, and FEV_1 measures airflow during the first part of the vital capacity maneuver.

In spite of the important benefits of spirometry discussed above, many barriers exist to the widespread use of office spirometry throughout the world. These are discussed below.

Unnecessary and misleading parameters

There are too many and unnecessary parameters. Historically, spirometry was used to measure vital capacity. Approximately 150 years ago, Tiffeneau introduced the concept of the timed vital capacity, which resulted in the FEV_1 . Other authors too numerous to mention have recommended FEV_{75} , FEV_3 , $FEF_{200-1200}$ (the forced expiratory flow between 200 and 1200 cm), and a maximum mid expiratory flow (MMEF) also more recently known as the forced expiratory flow between 25% and 75% of the vital capacity ($FEF_{25-75\%}$) and even the $FEF_{85-95\%}$ as important measures. They are not.

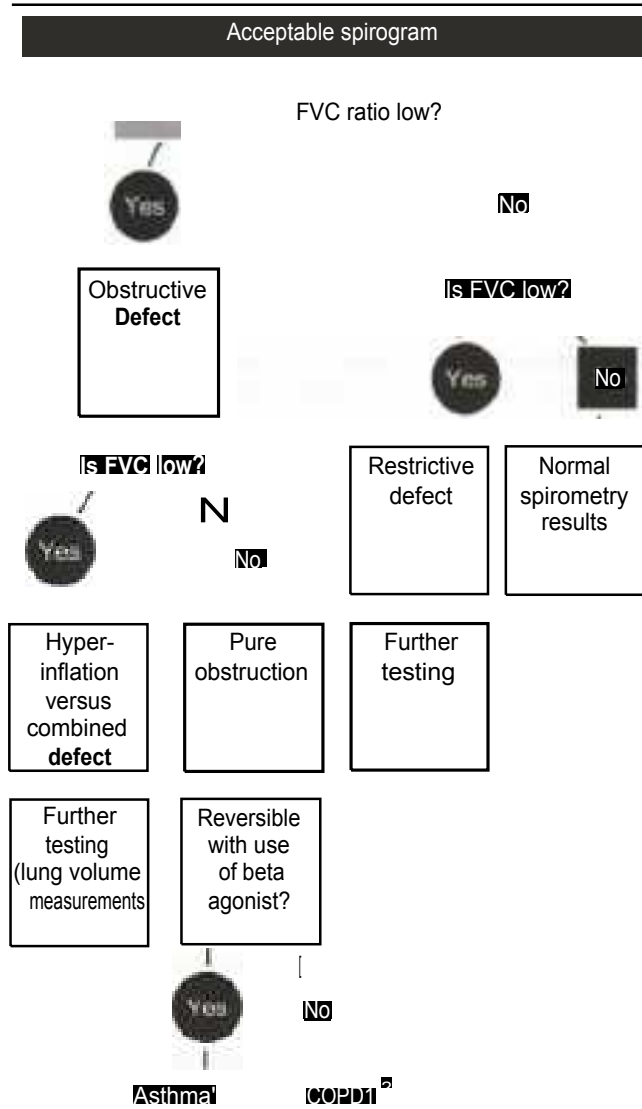
Things weren't too bad with the old-fashioned direct volume displacement spirometer, which required manual calculations of $FEF_{25-75\%}$ and other unnecessary, and probably useless parameters. The advent of the flow transducer, however, gave engineers the opportunity to print out as many numbers as they wanted from the expiratory flow signal. Thus, various flow rates at 75%, 50%, and 25% of the forced vital capacity were offered as more sensitive tests for small airways function. The "bells and whistles" imperative took hold and inspired the uninformed, including many pulmonologists, to add on additional "parameters" to the readout for the forced expiratory curve. These ancillary numbers have failed to offer anything significant to the classic two-parameter spirometry in the evolution of clinically significant airflow obstruction. They have not predicted the later development of FEV_1 or FVC abnormalities in asymptomatic smokers! The bottom line is that none of these tests offer any special clinical meaning above and beyond the FEV_1 , FVC, and FEV_1/FVC ratio. All of them should be abandoned.

Spirometer manufacturers, particularly those who offer office spirometers, should use only simple basic parameters of FEV_1 and FVC plus the ratio. The use of two-parameter spirometry (FEV_1 , FVC and the ratio) allows for one useful algorithm, which is displayed in Figure 1. Such a simple scheme should reduce the bewilderment faced today by primary care practitioners, who simply believe they can't understand spirometric interpretation. It's really this simple. All medical schools (see below) should foster this approach.

Spirometry is not taught effectively in medical schools

Probably the largest barrier is the fact that spirometry is not commonly taught in 126 allopathic or 22 osteopathic medical schools. Currently, medical students learn how to take a history, do a physical examination, and the importance of a basic database, which includes a chest radiograph

Figure 1. Algorithm for interpreting spirometry results



1. If clinical correlation is present.
2. Some COPD may have a reversible component.

COPD, chronic obstructive pulmonary disease; FEV₁, forced expiratory volume in one second; FVC, forced vital capacity.

and electrocardiogram and certain blood tests, in their impressionable years. However, they simply don't receive this same information about the value of spirometry. One exception is the Oklahoma State Medical School in Tulsa, where former Chairman James Seebass made spirometry a key part of the education curriculum beginning in medical school and particularly with emphasis in the sophomore year. Virtually every graduate from the Oklahoma State Medical Center understands and commonly does spirometry as part of their established practice.

Unfortunately, spirometry is not taught for what it is. Spirometry should be presented as a simple expression of

a complex process and compared with blood pressure. The factors that determine spirometric tests compared with blood pressure are summarized in Table 1. It is a big mistake to try to suggest that any one aspect of spirometry measures large airways function, small airways function, or elastic recoil. The fact is that spirometry measures all of these functions and their interdependence that are variously affected in chronic respiratory disorders, most commonly in asthma, COPD, and the restrictive interstitial lung disease states.

Spirometry simply has to take its place alongside the sphygmomanometer, the chest radiograph, and the electrocardiogram as an important database and a key indicator of both occult disease and the severity of disease, as well as the only means of effectively monitoring therapy such as powerful bronchoactive drugs. Spirometry is to dyspnea as the electrocardiogram is to chest pain!

A perceived lack of an established database for the value of spirometry in chronic obstructive pulmonary disease remains

One of the greatest criticisms of the widespread use of spirometry today encountered by all experts that try to teach about it is that there is no database that shows the importance of socioeconomic or health care benefit of spirometry in COPD. Previous investigators have stated that spirometry meets all the criteria as a test of early detection of COPD [17•]. However, not many practitioners accept this conclusive evidence of the value of spirometry.

An inadequate Italian study [18] is often cited as the basis for whether or not spirometry can be used to increase the efficacy of smoking cessation. The Italian study of 923 Italian smokers found a 1-year quit rate of 6.5% for those who received counseling with spirometry, compared with 5.5% in those who received only counseling; 4.5% of those who received only brief physician advice were able to stop smoking. [18] This study is probably not adequately powered [17•].

Spirometry has been shown to aid in the early diagnosis of COPD in a large study conducted in Poland [19]. A second

Table 1. Factors that determine spirometric tests compared with blood pressure

Blood pressure (sphygmomanometry) 120/80	Lung function (spirometry) 3.0 FEV ₁ /4.0 FVC
Cardiac output	Elastic recoil
Peripheral resistance	Airways resistance
Blood volume	Large airways
Blood viscosity	Small airways
Renin—angiotensin axis	Interdependence, etc.
	Muscular effort and coordination, etc.

study from Poland found spirometry to increase the effectiveness of smoking cessation efforts among those with airflow obstruction [201].

It has also been shown in two large European studies that spirometry is the key indicator of an accurate diagnosis of COPD in primary care physicians' offices [21',22].

Another study was in the population based upon 16,393 men from 34 municipalities in western Norway [23]. The FEV₁ was measured and the self-administered questionnaires were completed. A group of 2610 men who were current smokers age 30 to 45 with FEV₁ value in the lowest quartile were selected to receive a personalized letter from a respiratory physician, strongly advising them to quit smoking because they were at increased risk of smoking-related lung diseases as a consequence of their low lung function. A smoking cessation pamphlet was included emphasizing behavior modification, and a recommended quit date was offered. The others who received no report of their spirometry results or letter advising them to quit smoking, were reported 12-month sustained smoking cessation rates of 5.6% and the intervention versus 3.5% in the control group. After adjusting for age of a smoking onset, number of cigarettes smoked per day and history and occupational exposures to asbestos, it was found that patients who received a letter about smoking cessation and spirometry results were more likely to stop smoking ($P < 0.01$) [23]. The intervention in this study included spirometric information but did not isolate the effect of the spirometric information on the rate of smoking cessation. Similar studies have been reported elsewhere [22,23].

The need for simple, practical spirometers with quality control remains

A health care initiative known as the National Lung Health Education Program (NLHEP) has promoted the widespread use of spirometry [24']. Partly in response to this initiative, some spirometric manufacturers have tried to provide new and more user-friendly spirometry. One such device was evaluated at a health care fair in Colorado [16]. The accuracy of these simple spirometers used by nurses, who received only a short period of training, was quite comparable to that obtained by a standard laboratory device with the spirometry administered by a registered technologist.

The economics of spirometry are not well known

A recent analysis on the economics of initiating office spirometry in a six-man internal medicine group in Kirksville, MO has been reported [24*]. The spirometry laboratory occupied less than 147 square feet. In 1 year, 1179 spirometry tests were done and clinic revenue showed a \$40,000

surplus over operating costs [25]. The service often resulted in the new diagnosis of obstructive lung disease that had not been previously made. This became the foundation for initiating care for these patients. Having on-site service in this small community saved patients the time and cost of traveling 100 miles to have spirometry done in a pulmonologist's office [25']. Coding and numbers with reimbursements have been published [26].

Spirometry is not generally available

Spirometry is not generally available in many countries of the world. There is a critical need to be able to provide simple, inexpensive spirometry throughout the world, particularly in large countries where smoking is common, for example, Brazil, China, India, and Russia, where COPD is rapidly increasing. COPD is projected to become the third most common cause of death and the sixth most common cause of disability in the world by 2020 [27]. Other areas of the world have prevalent restrictive diseases such as Africa, where AIDS and tuberculosis are pandemic.

Even a simple, calibrated plastic expandable bag, previously described by the author, gives accurate measurements of forced vital capacity [28]. When used with a timing device, the FEV₁ could also be determined (Petty TL, Bliss PL, unpublished observations).

There is no question that spirometry has an established value as a powerful prognostic indicator in the assessment of both occult and overt respiratory diseases including COPD. The promotion of simple office or clinic spirometry will be an evolving process, to be fostered by the national Lung Health Education Program, the Global Initiative for Lung Disease (GOLD) [29], and other global efforts.

Conclusion

Spirometry is a highly useful, yet simple instrument for the measurement of expiratory air flow and volume. Spirometry is key to the diagnosis of obstructive ventilatory diseases, that is, asthma and COPD, and in monitoring responses to therapy. Spirometry also identifies restrictive diseases and helps to monitor therapy and predicts prognosis over time. Spirometry is a useful adjunct in smoking cessation.

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