(J Dhaka Med. Coll. 1998; 7(1) : 44-51)

REVIEW ARTICLE

CURRENT CONCEPTS ON PULMONARY FUNCTION TESTING

MD. RASHIDUL HASAN, MD. ALI HOSSAIN, ASIF MUJTABA MAHMUD

Introduction

The primary function of lung can be stated as two folds; first, the oxygenation of mixed venous blood; second the removal of carbon dioxide from that same blood. The two functions depend on the integrity of the airways, the vascular system and the alveolar septa. While treating patients suffering from breathing difficulties of various nature (asthma, COPD etc.) it is difficult to detect the actual degree of their airway obstruction. Vague symptoms and physical examination may often provide us misleading information about the degree of obstruction.

It is well known that no physician would treat hypertension without measuring blood pressure as the treatment depends to a great extent on the level of hypertension. So in modern treatment approach, assessment of the actual degree of illness through proper investigation is a rational approach for effective management of a patient. Similarly, assessment and treatment of asthma and patients with COPD are becoming easier as many diagnostic tools are now being used to assess the actual condition and prognosis of the disease. Computer based spirometry (Pulmonary function testing) is now available in our country which is found to be a valuable assessment tools to know the degree of illness of the patient.

So in our clinical practices it would be helpful to review the update knowledge regarding pulmonary function testing.

Pulmonary - Function Testing

Pulmonary -Function tests provide objective, quantifiable measures of lung function. They are used to evaluate and monitor diseases that effect heart and lung function, to monitor the effects of environmental , ocupational and drug exposures, to assess risks of surgery, and to assist in evaluations performed before employment or for insurance purposes. The indications for pulmonary-function tests are summarized in Table-I. Spirometry is the measurement of the movement of air into and out of the lungs during various breathing maneuvers. Such examinations, should be readily available and routinely used in doctor's chamber, diagnostic laboratory and hospitals where patients with heart and lung diseases are treated. Other common tests of lung function include the measurement of lung volumes, airway resistance, carbon monoxide diffusion capacity, and arterial-blood gas analysis.

Diagnostic Indications

Pulmonary-function tests are useful in diagnosing and managing pulmonary diseases. The recommendations of the National Asthma Education Program indicate that such testing is essential in the diagnosis and managemen t of asthma because of evidence that both patients and physicians have inaccurate perceptions of the severity of asthma that contribute to delays in treatment[1]. Indeed, underestimation of the exent of airflow (air way)

Institute of Diseases of the Chest and Hospital, Mohakhali, Dhaka.

obstruction is associated with increased mortality in asthma[2].

Pulmonary-function tests can identify abnormalities of lung function that might otherwise be over-looked and can exclude the possibility of some respiratory disorders such as chronic obstructive pulmonary disease. Physicians cannot identify obstructive or restrictive patterns reliably from history taking and physical examination alone[3-5].

When physicians ordering lung-function tests were asked to predict the results, they correctly predicted an obstructive pattern 83 percent of the time[4]. However, predictions of normal or restrictive patterns were correct in only 50% cases[4]. Besides identifying abnormalities, lung-function tests allow the severity of an abnormality to be quantified and the presence of reversible airflow obstruction to be determined.

Pulmonary-function testing is sometimes indicated when there may be more than one explanation for a patient's symptoms. For example, a smoker who presents with dyspnoea and obvious signs of congestive heart failure may also have obstructive lung disease. Failure to recognize and treat both disorders may limit the therapeutic response.

Screening and Monitoring

Pulmonary function tests are included in many evaluations of fitness and some routine physical examinations. Such testing may provide interesting information, but in the absence of symptoms, physical findings, or risk factors its clinical usefulness is questionable. There is little evidence to support a policy of screening the general population with spirometry[6]. Some subgroups (i.g., cigarette smokers and people exposed to known agents of lung injury, such as asbestos or di-isocyanates) are at higher risk of lung disease; screening and monitoring are appropriate for them[6,7]. It has been suggested that about 15 percent of cigarette smokers have in accelerated decline in the maximal volume of air exhaled, after a maximal inhalation, in the first second of a forced exhalation (e.e), the forced expiratory volume in one second, or FEV_1); ultimately, this condition leads to airflow obstruction and the possibility of early disability and death from chronic obstructive pulmonary disease[8]. Although the rates of loss of FEV_1 in smokers and nonsmokers overlap, nonsmokers tend to lose FEV_1 at a rate of 20 to 30 ml per year, whereas "sensitive" smokers (those with an accelerated decline in FEV_1) loss FEV_1 at a rate of 60-100ml/year. In people under 35 year of age, cessation of smoking is associated with improved lung function; for those older than 35, the accelerated decline in lung function slows to the normal rate associated with ageing[8-10]. Smokers with one normal spirometry cannot rest easy; they may still have an accelerated loss of lung functon that is detectable only by serial measurements. Smokers are more likely to stop smoking if they are informed of such functional abnormalities.

Serial measurement of lung function (monitoring)may be useful in tracking pulmonary expressions of diseases, quantifying responses to therapy, and making early diagnoses of lung injury after occupational exposures and drug or radiation therapy. Many diseases, including heart failure, rheumatoid arthrities, inflammatory bowel disease, and vasculitis affect the lungs either directly or as a result of the adverse effects of treatment[11]. Monitoring lung function allows the physician to identify pulmonary involvement in such diseases. For example, serial measurements of vital capacity (VC) may help a physician.

Quantifiy a patient's to therapeutic agents in congestive heart failure. In the Framingham study, decreases in VC were a better predictor of heart failure than were symptoms, examinations, or radiographic findings[12]. Improvements in VC may also indicate recovery from congestive heart failure[13].

Table-I

Diagnostic
To evaluate symptoms, signs and abnormal results of laboratory tests
Symptoms : cough, dyspnoea, wheezing orthopnoea, or chest pain
Signs : Overinflation, expiratory slowing cyanosis, chest deformity, wheezing, or unexplained crackles.
Abnormal results of laboratory tests : hypoxaemia, hypercapnia, polycythemia, or abnormal chest radiographs.
To measure the effect of disease on pulmonary function.
To screen persons at risk for pulmonary disease.
Smoker
Persons with occupational exposure to injurious substances.
Some persons at time of a routine physical examination.
To assess preoperative risk.
To assess prognosis.
Monitoring
To assess effectiveness of therapeutic interventions.
bronchodilator therapy.
Steroid treatment for asthma, interstitial lung disease, and the like
management of congestive heart failure.
Others
To provide information on the course of diseases affecting lung function.
Pulmonary disease, such as obstructive airways disease and interstitial lung disease,
Cardiac disease, such as congestive heart failure.
Neuromuscular disease, such as Guilain-Barre syndrome
To assess current status of persons with occupational exposure to injurious substances.
To assess adverse reactions to drugs with known pulmonary toxicity.
Evaluation of disability or impairment.
To assess patients as part of a rehabilitation program.
Medical
Industrial
To assess risks for an insurance evaluation.
To assess the condition of persons for legal reasons etc.
Public health
Epidemeological surveys

Numerous drugs are associated with lung injury[14-15]. The role of pulmonary-function testing in monitoring for drug toxicity is not clearly defined. In the case of amiodarone hydrochloride, an anti-arrhythmic agent, it is quite controversial, but monitoring of lung function may confirm or provide an early indication that an adverse pulmonary reaction has begun. The development of pulmonary fibrosis can be monitored with lung-funntion testing in-patients undergoing cancer chemotherapy or radiation therapy involving lung parenchyma. Lung-transplant recipients are commonly monitored with lung-function tests to detect early evidence of bronchiolitis obliterans[16-17].

Monitoring is useful only when adequate base-line studies are available for comparison. A change from a patient's base-line value is more likely to indicate pulmonary injury than is the traditional comparison of values measured in the patient with reference values obtained from population studies. Changes from base line that are as small as 5 to 10 percent may be substantial for a person and could be missed if only reference values are used in the comparison.

Consider, for example, a 40 year-old man who is 175 cm tall. His predicted VC, based on referecne values, is 4.99 liters (normal range , 2.79 to 6.11). If his VC at base line was 7 liters, it could decrease by up to 37 percent before his test results fell below the normal range.

The frequency and kinds of pulmonary function tests vary with the situation. If the primary involvement is in the airways (for example, in a lung-transplant recipient at risk of bronchiolitis), spirometric testing is adequate. If involvement of the lung parenchyma is likely (for example, in a patient receiving bleomycin), lung volumes and the carbon monoxide diffusing capacity (DLCO; also known especially in Europe, a "transfer factor") should also be measured. In congestive heart failure, lung volumes are primarily affected, and VC is the best index to monitor.

Preoperative Evaluation

Although the role of preoperative pulmonary-function testing remains conroversial[18], its goals are now more clearly defined[19-21]. They include helping to identify patients for whom the risk of surgery is prohibitive and helping to identify patients at increased risk of pulmonary complications, for whom better-informed decisions about preoperative and postoperative care can then be made.

There is general agreement that at the least, the preoperative pulmonary testing of patients for whom lung resection is being considered should include spirometry and measurement of arterial-blood gases. The abnormalities that suggest an increased risk of postoperative pulmonary complications and the need for further evaluation are as follows : VC less than 50 percent of the predicted value, FEV_1 less than 2 liters or less than 50 percent of predicted, or the presence of substanital hypoxaemia or hypercapnia. Studies designed to predict postoperative FEV_1 from ventilation or perfusion scans and in some cases, DLCO and exercise studies may help in further defining the risk[19-21]. Patients whose predicted postoperative FEV_1 is less than 0.8 liter or 40 percent of the predicted value are at very high risk.

For other surgery, the risk of postoperative pulmonary complications generally declines as the distance from the chest to the surgical site increases. Upper abdominal and thoracic operations not involving lung resection are associated with increased risks of pulmonary complications. Smokers and people with signs and symptoms suggesting of lung disease are most likely to benefit from preoperative screening with spirometry and blood gas analysis[21]. Lower abdominal and head-and-neck surgery are associated with lower surgical risks. Spirometric testing and blood gas analysis are likely to help only patients without prior lung-function tests whose preoperative evaluation suggests the presence of pulmonary disease[21].

Risk and Prognosis in Patients With Known Lung Dysfunction

Low levels of lung function even in patients who have never smoked cigarettes, are associated with a poor prognosis in patients with heart and lung disease. Studies consistently find that reduced lung function (usually FEV_1) is associated with an increased risk of death from chronic obstructive pulmonary disease, non-neoplastic respiratory diseases. Vascular diseases, lung cancer, and all cases of death considered together [22-25]. These findings are consistent among groups of patients, but it is not possible to predict the symptoms or mortality of individual patients accurately on the basis of FEV_1 alone.

Interpretation of Lung-Function Tests

Test quality remains the most important concern in lung-function testing. Variability (noise) is greater in pulmonary-function tests than in most other clinical laboratory tests because of the inconsistency of efforts by patients[26]. The American Thoracic Society (ATS), the European Respiratory Society, and other organizations have published standards designed to minimize the variability in these tests[27-31]. The elements that lead to high-quality test results are accurate equipment, good test procedures, an ongoing program of quality control, appropriate reference values and good algorithms for the interpretation of results. It is tempting to assume that all equipment on the marker is accurate. However, a 1990 evaluation of spirometer

revealed that only 57 percent met the standards of the ATS for accuracy[32]. Purchasers should insist on evidence that an instrument meets the trial program for spirometer that uses a calibrated 3.0 liter syringe and a few other simple checks[33] can be conducted easily in a physician's chamber. The accuracy of instruments that measure diffusing capacity, lung volume, and blood gases in some difficult. These machines are best used in setting where there are larger volumes of patients.

The interpretation of lung-function tests usually involves comparing values measured in patients with reference values from studies of populations of health nonsmokers. There are substantial differences between the equations used to predict normal lung function, because of differences among the populations studied as well as technical and procedural differences.

The first step in interpreting a lung-function tests is to assess and comment on test quality. Spirometric tracings should be examined to make sure they represent adequate effort by the patient, are reproducible,and contain no artifacts that would alter the test results (Table-III). If the requirements for quality are not met, tests should be interpreted (Table-IV) with caution. Some technical problems are so important that they prevent any interpretive statements from being made; other problem but do not totally eliminate the amount of interpretable information. For example, a set of spirometry may contain good information about VC but not about FEV_1., With computerized equipment, more than 20 different spirometric parameters can be reported. It is important to resist the temptation to use more than a few such parameters in the basic interpretation. Increasing the number of variables used in the test increases the number of false positive results[34]. In spirometry, there are several basic variables. VC is the maximal volume of air that can be exhaled after a maximal inhalation. It can be measured as two variables: Forced vital capacity (FVC) and slow vital capacity (SVC). Two other variables are FEV_1 and FEV_1 /FVC% (calculated as FEV_1/FVC x 100). In most cases these variables suffice to provide all the information needed to interpret a spirometry report.

Two basic types of lung dysfunction can be defined by spirometry : obstructive patterns and restrictive patterns. The primary criterion for airflow obstruction is a reduced FEV_1/FVC%. Other measurements of flow can be used to support conclusions based on this variable or to assist in making decisions when FEV_1/FVC% is borderline.

A restrictive pattern means that lung volumes are small. The primary criterion for this diagnosis is a reduction in total lung capacity (TLC), the volume of air in the lungs at the end of a maximal inhalation. However, the presence of restriction is commonly inferred from decreased FVC. FVC may also be reduced inthe presence of airflow obstruction, especially when exhalation time is short. When there is airflow obstruction and FVC is reduced, the possibility of restriction can usually be eliminated with evidence of over inflation from the physical examination or chest radiography

When there is any question about the cause of a reduced FVC, TLC should be measured. Even though restriction is defined by a reduced TLC, FVC has frequently been demonstrated to be more useful in following the course of restrictive chest diseases.

Table-V lists the criteria of the ATS for evaluating a response to the administration of a bronchodilator in the laboratory and assessing the importance of changes in FVC and FEV1. over time[34]. Treating a patient with a bronchodilator medication is a clinical, not a laboratory decision. A response to this therapy in the laboratory makes a clinical response to therapy more likely; nevertheless, the lack of such a response does not preclude a clinical response to long-term bronchodilator therapy. If the clinical evaluation suggests that such therapy may be effective, a long-term bronchodilator therapy can be instituted and followed by a reevaluation, both clinical and spirometric, in four to six weeks. As when patients are monitored in otherways, patterns of change are more apparent with serial measurements.

Classifying the severity of disease involves several complex issues. As general discussion and specific guidelines are provided in the statement by the ATS[34].

Table-III

Technical Requirements for Spirometry of Good Quality

At least 3 acceptable tests
Full inhalation before stat of test
Satisfactory start of exhalation
Evidence of maximal efforts
No hesitation
No cough or glottal closure during the first second
Satisfactory duration of test
Al least 6 seconds
Up to 15 seconds in patients with airflow obstruction
No evidence of leack
No evidence of obstruction of the mouthpiece.
Reproducible results
For FVC and FEV_1, the 2 largest values should be within 5 percent or 0.1 liter (whichever is larger) of each other
If these criteria are not met, continue testing
If the criteria are not met after 8 trials, stop testing and proceed with the interpretation, using the 3 best acceptable tests
Selection of tests value for interpretation
Selection from tests of acceptable quality
Selection of the largest value for FVC and FEV_1, regardless of the test used
For indexes of average or instantaneous flow, use values from the test with the largest value for FVC and FEV_1 combined

* From the statement of the American Thoracic Society[27].

Table-IV

Guidelines for the interpretation of Spirometry *
Choose statistically acceptable lower limits of normal
Evaluate and comment on test quality
Use FVC, FEV_1, and FEV_1/VC% as the primary guides for interpretation. (Increasing the number of parameters in the interpretation increases the incidence of false positive results). Values that are well above or well below the lower limits of normal can be interpreted with confidence. Interpret borderline values with caution, using clinical information to make decisions.
The primary indicator of airflow obstruction is a reduced FEV1/VC%
Once obstruction is diagnosed, classify the severity using FEV1 expressed as a percentage of the predicted value
Determine the response to bronchodilator therapy (See (table-V).
A restrictive pattern may be cautiously diagnosed from the spirometric examination when VC is reduced and FEV_1/VC% is normal. However, the definitive findings for a restrictive pattern is a reduced TLC.
The severity of restriction should be based on TLC if that value is available, and otherwise from VC.
Restriction cannot be diagnosed from the spirometric examination in the presence of moderate-to-severe airflow obstruction.

* From the statement of the American Thoracic Society[34].

Table-V

Response to Bronchodilator therapy and changes over time

Measure of response	Percent change in FVC or or FVE_1 Required for a substantial response	Comment
Current ATS recommendation	12	Both a percent improvement and an absolute improvement of 200 ml are required
Change from week to week Normal subject	≤ 12	
Patients with chronic obstructive pulmonary disease	≥ 20	

* From the statement of the American Thoracic Society[34].

Changes in FVC must not be due to a longer total exhalation time in persons with airflow obstruction

Conclusions

Sometimes only pulmonary function testing is the way to diagnose or differentiate a pulmonary disease. There are good reasons to seek quantifiable data about lung function. Interpreting the results of pulmonary-function testing requires careful attention to the equipment used, the patient's performance, and the reference values chosen. In cases in which disease or lung injury may develop over time, a person's own base-line values provide the best reference data.

References

1. National asthma education and prevention program. Expert Panel report-2 : guideliens for the diagnosis and management of asthma. Bethesda, Md. Department of Health and Human Services, 1997; 97-4051.
2. Sly MR. Mortality from asthma. J allergy Clin Immunol 1989; 84 : 421-34.
3. Hepper NJ, Hyatt RE fowler WS. Detection of chronic obstructive lung disease : An evaluation of the medial history and physical examination. Arch Environ Health 1969; 19 : 806-13.
4. Russel JN, Crichton NJ, Emerson PA, Morgan AD. Quantitative assessment of the value of spirometry. Thorax 1986; 41 : 306 -3.
5. Gentry SE, Hodge RH, Kaiser D, Walker FB Iv, Suratt PM. Pulmonary function testing in a general medical practice. J Community Health 1983; 8 : 263-8.
6. Screening for adult respiratory disease : official American Thoracic Society statement. March 1983; 128 : 768-74.
7. Hankinson JL. Pulmonary function testing in the screening of workers; guidelines for instrumentation, performance, and interpretation. J Occup Med 1986; 28 : 1081-92.
8. Fletcher C, Peto R, Tinker C, Speizer FE. The natural history of chronic bronchitis and emphysema : an eight-year study of early chronic obstructive lung disease in working men in London. Oxford, England : Oxford University Press, 1976.
9. Camilli AE, Burrows B, Knudson RJ, Lyle SK, Lebowitz MD. Longitudinal changes in forced expiratory volume in one second in adults : effects of smoking and smoking cessation. An Rev Respir Dis .1987; 135 : 794-9.
10. Peto R, Speizer FE, Cochrane AL et al. The relevance in adults of air-flow obstruction, but not of mucus hypersecretion, to mortality from chronic lung disease : results from 20 years of prospective observation. Am Rev Respir Dis 1983; 128 : 491-500.
11. Bates DV. Respiratory function in disease 3rd. ed. Philadelphia : W.B. Saunders, 1989.
12. Kannel WB, Seidman JM, Fercho W, Castelli WP. Vital capacity and congestive heart failure : the Framingham study. Circulation 1974; 49 : 1160-6.
13. Light RW, George RB, Serial pulmonary function in patients with acute heart failure. Arch Intern Med 1983; 143 : 429-33.
14. Rosenow EC III, Myers JL, Swensen SJ, Pisani Rj. Drug-induced Pulmonary disease : An update. Chest 1992; 102 : 239-50.
15. Rosenow EC III, Drug-induced pulmonary disease. In : Murray JF, Nadel JA, eds. Textbook of respiratory medicine. Philadelphia W.B. Saunders 1988; 2 : 1681-702.

16. Ettinger NA, Trulock EP. Pulmonary considerations of organ transplantation. Am Rev Respir Dis 1991; 144 : 433-5.

17. Starnes VA, Theodore J, Oyer PE et al. Evaluation of heart-lung transplant recipients with prospective, serial transbronchial biopsies and pulmonary function studies. J Thorac Cardiovascular Sung 1989; 98 : 683-90.

18. Williams-Russo P, Charlson ME, MacKenize CR, gold JP, Shires GT. Predicting postoperative pulmonary complications its a real problem ? Arch Intern Med 1992; 152 : 1209-13.

19. Dunn WE, Scanlon PD, Preoperative pulmonary function testing for patients with lung cancer. Mayo Clin Proc 1993; 68 : 371-7.

20. Celli RB, What is the value of preoperative pulmonary function testing ? Med Clin North am 1993; 77 : 309 - 25.

21. American College of Physicians. Preoperative pulmonary function testing. Ann Inter Med 1990; 112 : 793-4.

22. Anthonisen NR, Wright EC, Hodgkin JE. Prognosis in chronic obstructive pulmonary disease. Am Rev Respir Dis 1986; 133 : 14-20.

23. Tockman MS, Comstock GW. Respiratory risk factors and mortality. Longitudinal studies in Washington County, Maryland. Am Rev Respir Dis 1989; 140 : 56-63.

24. Foxman B, Higgins ITT, Oh MS. The effects of occupation and smoking on respiratory disease mortality. Am Rev Respir Dis 1989; 134 : 649-52.

25. Annesi I, Kauffmann F. Is respiratory mucus hypersecretion really an innocent disorder ? A 22-year mortality survety of 1,061 working men. Am Rev Respir Dis 1986; 134 :" 688-93.

26. Becklake MR. Concepts of normality applied to the measurement of lung function. Am J Med 1986; 80 : 1158-64.

27. Standardization of spirometry 1987 update statement of the American Thoracic Society. Am Rev Respir Dis 1983; 136 : 1285-94.

28. Standardized lung function testing : official statement of the European Respiratory Society. Eur Respir J 1993; 6 : Suppl 16 : 1-100.

29. Single Breath carbon monoxide diffusing capacity (transfer factor) : recommendations for a standard technique : statement of the American Thoracic Society. Am Rev Respir Dis 1987; 136 : 1299-307.

30. Gardner RM, Clausen JL, Epler G, Hankinson JL, Permutt S, Plummer AL. Pulmonary function laboratory personnel qualifications. Am Rev Respir Dis 1986; 134 : 623-4.

31. Gardner RM, Clausen JL, Cotton DJ, Crapo RO, Hankinson JL, Johnson RL Jr. Computer guidelines for pulmonary laboratories. Am Rev Respir Dis 1986; 134 : 628-9.

32. Nelson SB, Gardner RM, Crapo RO, Jensen RL. Performance evaluation of contemporary spirometers, Chest 1990; 97 : 288-97.

33. Gardner RM, Clausen JL, Crapo RO et al. Quality assurance in pulmonary function laboratories. Am Rev Respir Dis 1986; 134 : 625-7.

34. American Thoracic Society. Lung Function testing : selection of reference value and interpretative strategies Am Rev Respir Dis 1991; 144 : 1202-18.