Chapter 8

PULMONARY FUNCTION TESTING—SPIROMETRY TESTING FOR POPULATION SURVEILLANCE

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INTRODUCTION

Spirometry is a test of respiratory function that measures the volume of air that an individual can inhale and exhale, usually in a forceful manner. After the individual fills his or her lungs to maximal capacity, he or she is asked to exhale forcefully while the exhaled volume is measured over time until the expiration is complete. This volume–time relationship as graphed is known as a *spirogram*. The device used for the measurement is referred to as a spirometer. The important parameters determined by this test include the following:

- the total volume that is exhaled forcefully;
- the forced vital capacity (FVC);
- the volume of air that is exhaled in the first second of time;
- the forced expiratory volume in 1 second (FEV_1); and
- the ratio between these two values: FEV_1/FVC.

Spirometry is considered a screening test that is useful in the evaluation of a patient who presents with respiratory symptoms (eg, dyspnea, cough, sputum production, chest tightness, and wheezing). Thus, the results of spirometry can be interpreted according to specific patterns of normality or abnormality, including airflow obstruction, possible lung restriction, or a mixed pattern of obstruction and possible restriction. If the spirometry test results are interpreted as abnormal, the individual may then be referred for more complete testing and other evaluation.

TECHNICAL ASPECTS OF SPIROMETRY

The spirometers used for testing can either directly measure the volume of air exhaled (volume spirometers) or indirectly measure volume by integrating expiratory flows over time (flow spirometers). When volume spirometers are computerized, the change in volume can be quantified over time to determine the instantaneous rates of air exhaled. For flow spirometers, the flow rates of air are integrated over time to obtain measures of the expiratory volume of air. All spirometers used in clinical and research settings must have passed standards for accuracy, precision, and graphical display size as established by the American Thoracic Society (ATS).[1] In addition, because the test depends on the maximal effort of each individual being tested, the technician

- must be appropriately trained to explain the test to the subject,
- should coach the subject to help produce his/her maximal efforts, and
- be able to review each maneuver to determine if the effort was maximal and acceptable.

Each technician must have completed training provided by courses such as those approved by the National Institute for Occupational Safety and Health,[2] and demonstrate continued good testing technique when reviewed for technical quality by pulmonary specialists with feedback for the technician. Figure 8-1 shows an individual performing spirometry while being coached by an experienced technician.

Each spirometry maneuver must meet specific criteria established by ATS-recommended guidelines for acceptability. For a valid spirometry test session, there should be three acceptable maneuvers, with consistent (repeatable) results recorded for both the maximal FVC and the maximal FEV_1.[1] Trained technicians can identify maneuvers that meet acceptability and repeatability criteria.

Figure 8-1. Individual performing spirometry.

PROBLEMS WITH POOR QUALITY TESTING

If the spirometry testing maneuvers are not performed with adequate quality (meeting acceptability and repeatability criteria), then it is possible that false-positive or false-negative results may be reported. If so, unnecessary additional testing may be performed or necessary medical follow-up may not be conducted. Both of these errors can eventually add to the expense of a spirometry surveillance program.

INTERPRETATION OF RESULTS AND USE OF REFERENCE EQUATIONS

To permit confident interpretation of spirometry results, valid tests should be conducted whenever possible, meeting acceptability and repeatability criteria. Measured results are compared with reference equations to determine if the measured results are normal or abnormal. Abnormality is present if the values fall below the 5th percentile lower limit of normal[3] (LLN) based on the reference equations chosen. Reference values most often recommended for comparison were derived from spirometry testing performed as part of the Third National Health and Nutrition Examination Survey (NHANES III).[4,5] These reference values—derived from high-quality spirometry test results from healthy, randomly selected nonsmokers aged 17 and older from across the United States—would be the most appropriate reference values for use with service members and veterans.

SPIROMETRY IMPAIRMENT PATTERNS

Spirometry testing results can be interpreted as normal, showing airflow obstruction, possible restriction, or indicating a mixed impairment (both airflow obstruction and possible restriction). If an acceptable and repeatable testing session reveals an abnormal pattern (obstruction, possible restriction, or a mixed impairment pattern), then additional tests may be indicated to further evaluate the presence of a possible respiratory condition.

Airflow obstruction is based on the finding that the FEV_1/FVC ratio is below the LLN for that ratio. Airflow obstruction can be seen in pulmonary conditions, such as asthma, chronic obstructive pulmonary disease, bronchiolitis obliterans, and constrictive bronchiolitis.

Possible restrictive lung defect is suggested by spirometry testing when the FVC is below the LLN for that parameter. Restrictive patterns can be seen in any condition that limits the ability of the lungs and/or chest wall to expand: obesity, chest wall abnormalities (as might occur after trauma), pleural disease, or pulmonary interstitial/parenchymal disease. Spirometry can only indicate possible restrictive lung defect. To confirm the presence of restriction, additional testing—including measurement of lung volumes—is usually indicated.

SURVEILLANCE SPIROMETRY: WHO SHOULD BE TESTED?

Surveillance programs for respiratory disease must first determine which individuals should have spirometry testing. Because the development of a respiratory disease may be identified by the presence of respiratory symptoms and the finding of abnormal spirometry results, then individuals who present with persistent symptoms of dyspnea, cough, sputum production, chest tightness, and/or wheezing should have spirometry testing performed. It is also possible that the individuals without overt symptoms may have decrements in lung function from exposures that could eventually be diagnosed as a respiratory disease. To adequately measure significant decrements or declines in lung function as a result of environmental or occupational exposures, it would be necessary to have baseline lung function testing prior to exposures. For those in military service, this would mean testing all individuals who enter the service because it may not be known at that time if the individual would subsequently be exposed to adverse environmental/airborne toxic agents.

The cost of performing spirometry testing for every service member upon entering into service would be considerable. Estimated costs for testing all 2,255,100 service members upon entry are shown in Table 8-1.

DISADVANTAGES AND CONCERNS FOR PERFORMING BASELINE SCREENING SPIROMETRY FOR EVERY SERVICE MEMBER

In addition to the significant cost for performing baseline screening spirometry for every service member, there are also other considerations. One important issue is that the normal range of pulmonary function values is designed to exclude one in twenty normal healthy individuals since the LLN is set at the 5th percentile for all examined spirometry measurements, as discussed previously. Therefore, when large numbers of healthy service members are tested, a significant number of false positives should be expected. Because spirometry is an effort-driven test, false-positive results may also be seen in individuals with less than maximal efforts if not identified by the technician as unacceptable. All false-positive test results may lead to further evaluation with associated additional costs.

Identification of abnormal test results for an individual who may have no symptoms may limit that individual's ability for future employment or career choice. For those individuals who may have a previous diagnosis of a pulmonary impairment, identification of the severity of impairment may limit their ability for some assignments, including deployment.

There are also concerns for establishing a department-wide testing program:

- Who would assume leadership for this program?
- Where logistically would the testing be done?
- At what point in the early career of the service member would he or she be tested?
- Who would be assigned the task of reviewing, interpreting, and reporting all the results? Where would the data be stored?

TABLE 8-1

ESTIMATED COST FOR TESTING ALL SERVICE MEMBERS UPON ENTRY INTO SERVICE*

Item	Cost
1,000 spirometry technicians, salaries	$50,637,000
Training for technicians	$2,000,000
Spirometers (one per technician)	$5,000,000
Cost of server and databases	$200,000
Cost to review and interpret tests	$27,061,000
Cost for follow-up of abnormal results	$169,132,500
Administration of program	$200,000
Supplies	$11,275,500
Total cost of program	$265,506,000

*Total number of service members: 2,255,100. One technician can test 2,200–2,400 service members/year (need 1,000 technicians). Salary for one technician: GS-06, Step 5, $39,560 + 28% benefits ($11,077) = $50,637. Spirometry training, including travel: $2,000/technician. Cost to review and interpret each spirometry test: $12/test. Percentage of abnormal tests (true- and false-positive test results): 15%. Cost for follow-up of each abnormal test (further testing and medical evaluation): $500.

Other concerns would be the effort and cost for other proposed surveillance procedures, including symptom questionnaires and other routine medical diagnostic testing results.

COMPARISON OF BASELINE SPIROMETRY WITH POSTDEPLOYMENT SPIROMETRY TESTING

As described previously, identification of a deployment-related respiratory condition would include evaluation of an individual who presented with respiratory symptoms and was then found through additional testing to have either abnormal lung function test results or significant decrements in lung function when compared with baseline test results. Less consensus exists about the criterion for a significant decrement in spirometry test results than has occurred for the cross-sectional interpretation of pulmonary function results relative to the normal range. Since 1991, the ATS has stated that a 15% decline in FEV_1 would be considered to be a significant change, even if that postvalue by itself was found to be in the normal range based on a reference equation.[3] Thus, the individual's test results may have been above average (ie, high in the normal range) to begin with. More recent reports using regression analysis would suggest that, depending on the technical quality of the test and the resulting precision of the data being examined, smaller decrements in lung function might be considered to be significant.[6]

Another option would be to test service members pre- or postdeployment who present with respiratory symptoms.

SUMMARY

Surveillance spirometry performed on every individual who enters military service has the advantage that, if deployment-related respiratory illnesses did occur, having accurate baseline values would allow comparison to test results obtained after deployment. The logistics and costs for performing such baseline testing are considerable, as described previously, which may make such testing prohibitive. In addition, there are other concerns for such testing, including limiting the career choices for asymptomatic individuals who were found to have abnormal results from this baseline testing. The advantages and disadvantages of such baseline testing, including the expected false positives associated with using the 5th percentile LLN, would have to be examined closely before deciding on implementation.

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