How to Make Sure Your Spirometry Tests Are of Good Quality

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Poorly performed spirometry greatly increases the risk of misinterpreting spirometry results. The most common cause of erroneous results is suboptimal patient coaching. Use exaggerated body language to demonstrate each of the 3 phases of the forced vital capacity (FVC) maneuver. The first phase of the maneuver (the maximally deep breath) is the most important and should receive the most emphasis. In the second phase (the blast) startle the patient to prompt maximum flow during the first second. In the third phase do not yell at the patient to keep blowing; instead, draw the patient's attention to the movement of the bell of the volume spirometer, the computer incentive display, or the audio tone of the flow-sensing spirometer, which shows that he or she is continuing to get some air out. Pay attention to the patient's body language as you coach him or her through the 3 phases. Facial expressions and body language are much more important than telling the patient what to do. Use the latest National Health and Nutrition Examination Survey (NHANES III) reference equations and the ratio of forced expiratory volume in the first second to forced expiratory volume in the first 6 seconds (FEV_1/FEV_6). Young, old, and sick patients can produce high-quality, reproducible pulmonary function test results. Grade pulmonary function test efforts with the scholastic grading system (A, B, C, D, and F). Implement a centralized spirometry quality assurance program. Test your spirometers daily. Be cautious in making corrections for body-temperature-and-pressure-saturated. *Key words: spirometry, quality control, pulmonary function tests.* [Respir Care 2003;48(8):773–776. © 2003 Daedalus Enterprises]

Introduction

Spirometry has been around for over 150 years and yet is still done with suboptimal quality that causes false positive and false negative results.[1] The primary reason is a misapplication of accurate instruments. Almost all currently available spirometers pass the American Thoracic Society (ATS) recommendations for accuracy and reproducibility,[2] but these valuable instruments are often misused in clinical settings. Poor quality spirometry testing in hospitals was recently reported by Stoller et al.[3]

Coaching the Subject

During my visits to pulmonary function laboratories in various hospitals, I have noticed that the technician (oftentimes a respiratory therapist) misdirects his or her enthusiastic coaching of the forced exhalation maneuvers. What I often hear technicians say is, "Okay, take a deep

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breath and blow out fast. . . *Blow, blow, blow, blow, keep going, keep going, keep going, keep going*." I think the emphasis should be on the first phase of the spirometry maneuver (maximum inhalation), which is often ignored.[4] Coaching ought to start with body language. Say, "I want you to take as deeeeep a breath as possible." and stand up on your toes, with your shoulders thrown back and your eyes wide open; then say, "*Deeper*." You can obtain much larger vital capacities and FEV_1 by emphasizing that deep inhalation.[5]

The second priority is to maximize the blast during the initial exhalation (the second phase of the forced vital capacity [FVC] maneuver). Yell, clap your hands, or click your fingers near the patient's ear so as to startle the patient into the delivering his or her fastest possible peak flow, which occurs during the first one-tenth second of the blast.

During the third phase of the FVC maneuver, instead of yelling at the patient to keep blowing, draw his or her attention to the motion of the bell of the volume spirometer, the computer incentive display, or the audio tone of the flow-sensing spirometer, which shows that he or she is continuing to get out some air. Stoller et al have shown that it is actually counterproductive to yell at patients with airway obstruction to blow hard, because a higher transthoracic pressure during the final several seconds causes premature airway collapse.[6] Instead, patients should be quietly told to "keep going, I can see you're still getting more air out." Instruct them quietly until a plateau is reached on the volume-time spirogram. If you are (wisely) using the new FEV_6 equations from the NHANES III report[7] instead of the FVC equations, you can stop at 6 seconds. If your laboratory is not yet using the NHANES III equations, discuss with your medical director the value of switching to those equations and using the FEV_1/FEV_6 ratio to detect airway obstruction.[8]

Instrument errors are now much less common than technician errors. The maneuver errors I frequently see include hesitating or slow starts, coughing during the first second, and quitting too soon.[4] I think that just following the ATS spirometry standards is not adequate to minimize the false positive and false negative rates.[9]

Facial expressions and body language are much more important than telling the patient what to do. If you recite all of the steps of the procedure (like flight attendants do before each take-off), by the time you're done the patient probably will have forgotten the first step, which is the most important. Showing enthusiasm, being a cheerleader, using body language, and observing the patient's body language are highly important to obtain good spirometry results.

See the figures in the appendix of the 1995 ATS spirometry standards document for great examples of poorly performed spirometry.[10]

The third phase of the FVC maneuver is the last few seconds of the exhalation. If exhalation is not complete (ie, the end-of-test criteria are not met), the FVC will be underestimated and the interpretation might be that the patient suffers restriction, when in fact the patient may have normal lung volumes. Use of the new FEV_6 prediction equations will prevent you from having to "flog" patients for prolonged periods, and will prevent syncope, which occurs most commonly in stronger young men who are trying to impress the technician. The FEV_6 is much more repeatable from visit-to-visit than is either the slow vital capacity or FVC. A recent report shows that the FEV_1/FEV_6 is as good as the traditional FEV_1/FVC for predicting subsequent decline in lung function in cigarette smokers.[8] The rate of FEV_1 decline in adult smokers is a sensitive index of developing chronic obstructive pulmonary disease.

Reproducibility

Once you have obtained 2 or 3 acceptable maneuvers from the patient, then you should work on achieving reproducibility.[11] Most of the time when the FEV_1 or FVC are not reproducible, the problem is a variable degree of inhalation effort during the first phase (maximum inhalation).[12] We have been pushing manufacturers to include automated maneuver quality checks, both for acceptability and reproducibility, in their software.[13] The next time you need to purchase new spirometers, look for devices that have that feature.

A study I did at Mayo Clinic showed how well patients can match their FEV_1 values within a test session.[14] Nine of 10 matched their FEV_1 values within 150 mL. In subsequent studies I've seen patients with airways obstruction do even better. Even patients with severe chronic obstructive pulmonary disease can match FEV_1 values within 100 mL.[15] Thousands of children in a California study matched FEV_1 values within 150 mL.[16]

The causes of excessive variability within a spirometry test session are (1) suboptimal inspiratory coaching, (2) a poor expiratory blast, and (3) lack of reaching a plateau. Some flow sensors have a tendency to clog as more and more maneuvers are done within 10 minutes. This progressive clogging causes poor reproducibility in a few cases. Only 1 in 100 patients with asthma will have trouble repeating their highest FEV_1 because of maneuver-induced bronchospasm, so that's rarely a good excuse for not achieving a good match between the highest and second highest FEV_1.[17]

Quality Improvement and Assurance

I am a proponent of grading the quality of pulmonary function tests (FEV_1, FVC, and diffusing capacity of the lung for carbon monoxide). I believe that the physician who ordered the test should be told the degree of confidence he or she should place in the results. I recommend a simple scholastic-type grading system: A, B, C, D, or F.[18]

In research studies in which the primary outcome is change in lung function it's very important to have a centralized quality assurance program for spirometry.[19,20] A skilled technician grades the quality of each test done in the other study sites. Such a program not only encourages quality testing throughout the study but also improves reproducibility and comparability from study site to study site.

Can young children and elderly persons with lung disease really meet the ATS acceptability and reproducibility criterion? Yes. A study by Malmstrom included data from over 60 different sites and 3,000 study subjects, ages 6 through 86.[17] About three fourths of the study participants were able to achieve an A or B grade at the time of their first study visit, which means either meeting or exceeding the ATS criterion for FEV_1 acceptability and reproducibility. Ten percent of the study participants were able to get only one acceptable maneuver, and such test sessions were given a quality grade of D. Overall spirometry quality improved with each visit. After 5 or 6 visits 90–95% of the study participants got good spirometry grades (A or B).

What about all the old folks who we study in the pulmonary function lab? In the Cardiovascular Health Study 5,000 elderly people did just as well as younger people in achieving good quality spirometry.[21] The automated spirometer told the technician immediately whenever a maneuver was unacceptable or didn't match the best previously performed maneuver. Each technician got a spirometry quality report for the tests they performed the previous month. Results from the Lung Health Study, published in 1991, showed that when the quality of spirometry testing was graded and reported back to the technicians, their grades improved month by month.[18] Most of the 20 technicians were not respiratory therapists and had no prior experience doing spirometry.

The accuracy of your spirometer should be checked every day of use.[10] Traditional volume-sensing spirometers usually remain accurate for many years, unless they leak. However, many lack an internal temperature sensor to accurately make corrections for body-temperature-and-pressure-saturated (BTPS). If the room temperature is entered for BTPS, correction errors of up to 10% in the reported FEV_1 and FVC can result, since the interior of the spirometer warms up as patients repeatedly blow warm air into it.[22] The temperature of air inside a volume spirometer varies widely from morning to afternoon, from day to day, and from season to season. Therefore, the internal spirometer temperature should be measured for every maneuver, for accurate BTPS corrections.

Summary

Poorly performed spirometry greatly increases the risk of misinterpreting the results. The clinician who coaches the patient is the most likely cause of such false positive and false negative results. Using exaggerated body language to demonstrate each of the 3 phases of the FVC maneuver is the best way to improve spirometry quality. The first phase is the most important: the maximally deep breath. Pay attention to the patient's body language as you coach them through the 3 phases. Look at the spirometry curves only at the end of each maneuver. Use the NHANES III reference equations and use FEV_6 so you will not need to "flog" the patient to reach a flat plateau at the end of each maneuver.

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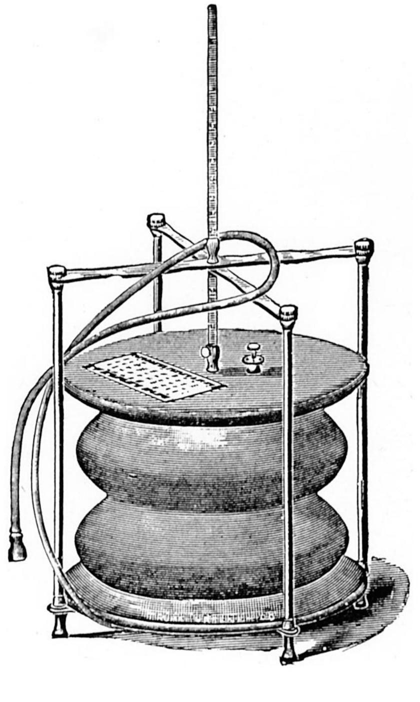

Denison's Spirometer from *Exercise and Food for Pulmonary Invalids.*
Charles Denison AM MD. Denver: The Chain & Hardy Co ; 1895.
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