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Comparison of FEV_6 and FVC for detection of airway obstruction in a community hospital pulmonary function laboratory

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Summary The National Lung Health Education Program recommends that primary care providers perform spirometry tests on cigarette smoking patients 45 years or older in order to detect airways obstruction and aid smoking cessation efforts [Ferguson GT, Enright Pl, Buist AS, et al. Office spirometry for lung health assessment in adults: a consensus statement from the national lung education program. *Chest* 2000; **117**: 1146–61]. An abbreviated forced expiratory maneuver that requires exhalation for 6 s (FEV_6) has recently been proposed as a substitute for forced vital capacity (FVC) to facilitate performance of such spirometry. We set out to assess the accuracy of diagnosis of obstruction and abnormal pulmonary function using FEV_6 in comparison to FVC in a community hospital population. One hundred pulmonary function tests performed at a community hospital were randomly selected and retrospectively analyzed. Sixty-three of the 100 tests had satisfactory 6-s expiration and were subject to further analysis. We compared the spirometric interpretation using Morris predictive equations for FEV_1/FVC and Hankison predictive equations for FEV_1/FVC and FEV_1/FEV_6. The Hankison set of equations is the only published reference formulas for prediction of FEV_6. We found that versus our Morris gold standard, Hankison based FEV_1/FVC interpretation was 100% sensitive and 67% specific for the diagnosis of obstruction and 100% sensitive and 65% specific for the diagnosis of any abnormality. The Hankison based FEV_1/FEV_6 interpretation was 97% sensitive and 47% specific for diagnosing obstruction and 100% sensitive and 50% specific for identifying any abnormality versus the Morris FVC based gold standard. In

Abbreviations: ATS, American Thoracic Society; BTPS, body temperature, ambient pressure, and saturated with water vapor; FEV_1, forced expiratory volume at 1 s; FEV_1/FEV_6, forced expiratory volume at 1 s divided by forced expiratory volume at 6 s gives a ratio used to diagnose obstruction; FEV_1/FVC, forced expiratory volume at 1 s divided by forced vital capacity gives a ratio used to diagnose obstruction; FEV_6, forced expiratory volume at 6 s; FVC, forced vital capacity; PFT, pulmonary function test

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conclusion, in our hospital based pulmonary function laboratory, FEV_6 based interpretation has excellent sensitivity for detection of spirometric abnormalities. However, its moderate specificity may hinder its utility as a screening test. Further testing is necessary to determine its reliability in different patient populations with less highly trained operators.

Introduction

The National Lung Health Education Program recommends that primary care providers perform spirometry tests for patients 45 years or older who report smoking cigarettes in order to detect airways obstruction and aid smoking cessation efforts.[1] Standard spirometry requires multiple forced vital capacity (FVC) maneuvers that end when the patient exhausts his/her exhalation. The FVC maneuver can cause patient discomfort and is poorly reproducible unless the results are expertly supervised. Recently, an abbreviated forced expiratory maneuver that requires exhalation for only 6 s (FEV_6) has been proposed as a substitute for FVC.[2,3] The shorter time may reduce the risk of syncope and makes it unnecessary to measure low flows at the end of the maneuver rendering the spirometer less expensive and easier to use by inexperienced personnel. This new spirometry, named office spirometry, utilizes the FEV_1/FEV_6 rather than FEV_1/FVC to detect airway obstruction.

Widespread acceptance of this FEV_6 based spirometry may be hindered by concerns about generalizability and broader utility. Only one set of predictive equations for FEV_6 exists (Hankison et al.[4]), and the validity of these equations as a substitute for FVC has been shown only in select laboratories serving large, homogenous referral populations.[2,3] Because of differences based on population age, height, weight, and ethnicity, the American Thoracic Society (ATS) recommends validating predictive equations against a particular pulmonary function laboratory's own population. In addition, comparison of Hankison FVC prediction to other predictive formulas has not been previously been undertaken. Presumably, if Hankison's equations do not predict FVC accurately in a particular population, they would be unlikely to predict FEV_6 accurately in that population.

Although office spirometry has been chiefly advocated as a screening tool for obstruction in smokers, once deployed in the primary care office, primary physicians may be tempted to use it to screen for other types of pulmonary disease. The accuracy of spirometry relying on FEV_6 for discerning non-obstructive pulmonary abnormalities has not been assessed, so its suitability for broader uses is unknown.[5]

In this study, our primary objectives were to assess the concordance of Hankison FVC based diagnosis of obstruction to diagnoses generated by applying the Morris predictive equations[5,6] (our lab standard). We then compared the accuracy of FEV_6 based diagnosis to both Morris and Hankison based FVC diagnosis to detect obstruction in patients tested in our community hospital pulmonary function laboratory.

Our secondary objective was to evaluate the ability of FEV_6 based analysis to detect any abnormality of spirometry diagnosed using FVC interpretation based on both Morris' and Hankison's equations.

Methods

We randomly and retrospectively selected 100 pulmonary function tests performed at a community hospital in accordance with ATS standards between September and October 2001. All spirometry was performed on a Collins GS system with a Stead-Wells volumetric spirometer operated by Collins GS Plus/SQL Software version 3.2 with a DEC Celebris computer.

For patients with 6 s of expiration, the pre-bronchodilator volume vs. time curve was back extrapolated to identify the start of test. FEV_1 and FEV_6 were determined based on the total volume exhaled at 1 and 6 s, respectively, from the start of test point. The best of 3 suitable curves was evaluated as per ATS criteria, FEV_1, FEV_6, and FVC were then hand calculated and adjusted to BTPS.[7]

Normal values for FEV_1, FVC, and FEV_1/FVC were predicted using Morris et al.[6] and Hankison[5] predicted equations. Normal values for FEV_6 and FEV_1/FEV_6 were predicted using Hankison predictive equations.

Each spirogram was classified 3 times using Morris based FEV_1/FVC criteria (Morris-FVC), Hankison based FEV_1/FVC criteria (Hankison-FVC), and Hankison based FEV_1/FEV_6 criteria (Hankison-FEV_6). The criteria used were:

Normal: FEV_1 80–100% of predicted and FVC (or FEV_6) 80–100% of predicted and FEV_1/FVC (or FEV_1/FEV_6) $\geqslant$100% of predicted.

Obstruction: FEV_1/FVC (or FEV_1/FEV_6) $<$100% of predicted and $FEV_1<100\%$ of predicted.

Abnormal: Any spirometry result not classified as normal. This class includes spirograms diagnosed as obstructed using the above criteria.

Sensitivity and specificity were calculated utilizing standard formulas from two-by-two tables.

Results

The study population consisted of 46 males and 54 females, median age 63.5 years (range from 22 to 91 years) (Table 1). Our population was primarily Caucasian. Eighteen out of the 100 patients expired for greater than 8 s, and 45 patients expired for 6–8 s. Thirty-seven patients exhaled for less than 6 s and, therefore, did not meet end of test criteria for FEV_6. These records were not further evaluated, leaving 63 patients with evaluable spirograms.

Table 1 Demographic characteristics of the investigated population.

Demographics	Category	Statistics
Sex	Male	46 (46%)
	Female	54 (54%)
Race	Caucasian	92 (92%)
	African-American	8 (8%)
Age		Median 63 years Range 22–91 years
Height	Male	Median 175 cm Range 150–190 cm
	Female	Median 160 cm Range 137–180 cm
Weight	Male	Median 83 kg Range 52–173 kg
	Female	Median 65 kg Range 39–205 kg

Among the 63 patients with evaluable spirograms, Morris-FVC identified 33 obstructed patients. Of those 33, Hankison-FVC and Hankison-FEV_6 correctly classified 33 and 32 patients, respectively. However, Hankison-FVC incorrectly classified 10 additional patients as being obstructed; Hankison-FEV_6 misclassified 16 additional patients as being obstructed. The sensitivity and specificity for identifying Morris-FVC obstruction was 100% and 67%, respectively, for Hankison-FVC and 100% and 65% for Hankison-FEV_6 (Table 2). If one utilized the Hankison-FVC rather than the Morris-FVC as gold standard, Hankison-FEV_6 yielded a sensitivity of 98% and specificity of 70% for detecting obstruction.

When more generally analyzing the ability to separate normal from abnormal spirograms, Morris-FVC identified 43 of the 63 patients as abnormal. Hankison-FVC and Hankison-FEV_6 both correctly classified all 43 patients; however, an additional 7 and 10 patients, respectively, were classified as abnormal. The sensitivity for identifying Morris-FVC abnormality was 100% for both Hankison-FVC and Hankison-FEV_6; the specificity was 65% and 50%, respectively (Table 3). Utilizing the Hankison-FVC as gold standard, Hankison-FEV_6 yielded a sensitivity of 100% and specificity of 77% for diagnosing abnormal spirograms.

Three cases were diagnosed as obstructed by Hankison-FEV_6 but not by Hankison-FVC. They are displayed in Table 4. In one case, the FEV_1/FEV_6 ratio is 99.8% of predicted.

Discussion

The results of our study show that FEV_6 based interpretation is a sensitive but non-specific method for the detection of obstruction when performed on referred patients in a hospital pulmonary

Table 2 Detection of obstruction.

Gold standard	Investigated interpretation	Sensitivity (%)	Specificity (%)
Morris-FVC	Hankison-FVC	100	67
Morris-FVC	Hankison-FEV_6	97	47
Hankison-FVC	Hankison-FEV_6	98	70

Obstruction is defined as in the Methods section of the manuscript. Gold standard, the interpretive strategy yielding the "correct" diagnosis of obstruction; Investigated interpretation, the interpretative strategy compared to the "gold standard" diagnosis.

Table 3 Detetction of abnormal spirometry.

Gold standard	Investigated interpretation	Sensitivity (%)	Specificity (%)
Morris-FVC	Hankison-FVC	100	65
Morris-FVC	Hankison-FEV_6	100	50
Hankison-FVC	Hankison-FEV_6	100	77

Abnormal spirometry is defined as in the Methods section of the manuscript. Gold standard, the interpretive strategy yielding the ''correct'' diagnosis of abnormal spirometry; Investigated interpretation, the interpretative strategy compared to the ''gold standard'' diagnosis.

Table 4 Hankison discordant obstruction results—patients who had normal spirometry when analyzed using Hankison-FVC who had obstruction when analyzed with Hankison-FEV_6.

FEV_1/FVC classification	FEV_1/FEV_6 classification	Sex	Age (yr)	FEV/FVC (%)	FEV_1/FEV_6 (%)	Expiratory time (s)
Normal	Obstructed	M	57	104	99.8	6.0
Normal	Obstructed	M	71	102	96	6.2
Normal	Obstructed	F	50	101	98	6.0

function laboratory with a diagnostic spirometer. Our sensitivity ranged from 97% to 100% (depending on the gold standard used) and is consistent with work done by Swanney et al.[2] who reviewed 337 cases and found that Hankison-FEV_6 vs. Hankison-FVC was 95% sensitive in detecting obstruction. In contrast, we found that specificity for FEV_6 based calculations to detect obstruction ranged from 47% to 70%. This is distinct from Swanney who demonstrated 97.4% specificity for Hankison-FEV_6 vs. Hankison-FVC for detecting obstruction.

As the ATS spirometry criteria state,[5] population characteristics are an important factor in choosing reference values for the population being evaluated. Our pulmonary function laboratory utilizes the Morris reference equations based on results obtained from testing a cohort of normal subjects. As a first step in our analysis, we compared the Hankison predictive equations for FEV_1 and FVC to the results we obtained using the Morris predictive equations. This analysis revealed that the Hankison predictions were 100% sensitive but only 67% specific in diagnosing obstructive spirometry. The Hankison predictive equations were generated from the third National Health and Nutrition Examination Survey and included an oversampling of African-American and Mexican-American populations. Our population was overwhelmingly Caucasian, and this may explain why the Hankison equations demonstrated only moderate specificity.

Once we had determined the performance of Hankison-FVC based analysis, we sought to compare Hankison-FEV_6 based interpretation to our gold standard Morris-FVC based diagnosis. Hankison-FEV_6 was very sensitive for obstruction at 100%. However, the specificity of Hankison-FEV_6 for obstruction was only moderate at 47%. This result was not surprising given the moderate specificity of Hankison-FVC for predicting results generated with Morris-FVC.

To further explore the characteristics of Hankison based FEV_6 interpretation in our population of patients; we compared Hankison-FVC to Hankison-FEV_6 for diagnosing obstruction in our patients. Using Hankison-FVC as our standard, we classified 43 patients as obstructed. Hankison-FEV_6 classified 48 patients as obstructed; 42 overlapped the Hankison-FVC obstructed patients, and 6 were normal based on FVC criteria yielding a sensitivity of 98% and a specificity of 70% for detecting obstruction. Although the specificity is improved relative to comparison with our Morris-FVC based gold standard, it is much lower than the 97.4% specificity reported by Swanney et al.[2] It is not clear why our results differ from Swanney. Their study was conducted in New Zealand which may represent a different population despite the fact that 100% of their tested population was Caucasian. Our study evaluated only 63 patients compared to 337 in the Swanney study.

When considering the use of FEV_6 based office spirometers for screening, one can argue that diagnosing obstruction is not important. Rather, utilizing a spirometer that can reliably separate normal from abnormal pulmonary function is crucial. If screening spirometry is abnormal, patients can then be referred for formal, full pulmonary function tests to better characterize their specific derangements. With that in mind, we

re-analyzed our data classifying the spirometry only as normal or abnormal based on our 3 different sets of predictive equations. For diagnosing abnormal spirometry using Morris-FVC as the reference, Hankison-FVC and Hankison-FEV_6 exhibited almost identical performance as when diagnosing obstruction, demonstrating a high sensitivity and a moderate specificity. Using Hankison-FVC as the gold standard, Hankison-FEV_6 exhibited good sensitivity and was more specific for the diagnosis of abnormal spirometry than for the diagnosis of obstruction (77% vs. 70%). One of the three discordant cases (normal by Hankison-FVC; abnormal by Hankison-FEV_6), had an FEV_1/FEV_6 ratio of 99.8%. If we consider that to be a normal result, the specificity of Hankison-FEV_6 for predicting abnormal spirometry rises to 83%.

Several other issues are pertinent when considering the use of FEV_6 for screening office spirometry. In both Swanney's and the current study, trained technicians obtained the spirometry. However, office spirometry is designed to be conducted in the primary care setting by less well-trained operators. Thus its reliability in the office setting without trained technicians is still unclear.

Thirty-seven percent of our cases did not achieve an FEV_6. This is not surprising since healthy young adults empty their lungs in less than 6 s, and comorbid illnesses and patient fatigue may cause patients to end expiration prior to 6 s. The ATS criteria allow the substitution of FVC for FEV_6 as an end of test criterion when expiratory time is less than 6 s providing that the effort is good as demonstrated by reaching an expiratory plateau. This determination, however, requires the operator obtaining the test to achieve a technically good FVC maneuver. Only 18% of our population expired for longer than 8 s. Forty-five percent of our population expired for a duration of 6–8 s. We speculate that many of these patients would not have achieved the 6 s end-of-test criterion if not encouraged by highly trained respiratory personnel.

Conclusion

Spirometry based on measurement of FEV_6 rather than FVC has been recommended for screening smokers in order to encourage smoking cessation.[8] This study suggests that FEV_1/FEV_6 (and FEV_1/FVC) interpreted using the predictive equations of Hankison are a sensitive method for the detection of obstruction or abnormal pulmonary function when performed in a hospital pulmonary function laboratory. However, in our population, FEV_1/FEV_6 (and FEV_1/FVC) based interpretations are only moderately specific, potentially leading to further investigation of a large number of normal patients.

This study and previous validation work have been done with a homogeneous population of primarily Caucasian patients, in standardized settings, using trained personnel to administer and read the pulmonary function tests. At present, there is only one set of predictive equations available to guide interpretation of the FEV_6 based results. Based on this, we believe that further work should be done to confirm the diagnostic accuracy of this method of spirogram interpretation before it can be recommended for general office screening.

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