Grading the Severity of Obstruction in the Presence of a Restrictive Ventilatory Defect*

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Study objectives: No recommendation currently exists for grading the severity of airway obstruction in the presence of additional restriction. The grading of airway obstruction is currently based on the FEV$_1$ (American Thoracic Society [ATS] recommendations), while prior recommendations by the Intermountain Thoracic Society (ITS) graded the severity of obstruction based on the FEV$_1$/FVC ratio. The objective was to compare the grading of airway obstruction using the percent predicted FEV$_1$ (ATS) with a confidence interval-based system (ITS), with particular focus on pulmonary functions in patients having both airway obstructions and restrictions.

Design: Retrospective analysis.
Setting: Tertiary medical center.
Patients: A retrospective analysis of 21,499 patient pulmonary function tests (PFTs) was performed. The predicted values of Crapo and coworkers were used.

Measurements and results: The distribution of the severity of the obstruction was compared using the ATS and ITS methods for PFTs with normal, increased, or decreased total lung capacity (TLC). Analysis was performed using the $\chi^2$ method. Of the 21,499 PFTs that were analyzed, TLC was measured in 28% (5,962 PFTs). In this cohort, 44% (2,619 PFTs) gave evidence of obstruction. Of these, 147 PFTs demonstrated additional restriction. While the ATS criteria graded 133 of these PFTs (90%) as being severe, the ITS criteria graded only 4 PFTs (3%) as severe (the severity distribution between the methods was significantly different [$p < 0.01$]).

Conclusions: In view of the possible overestimation of the severity of obstruction in PFTs with concurrent restriction using the percentage of predicted FEV$_1$ values, consideration should be given to grading the severity of obstruction on the basis of the FEV$_1$/FVC ratio in this specific subset of PFTs.

Key words: American Thoracic Society; obstructive airways disease; pulmonary function test; restrictive lung disease; severity; spirometry

Abbreviations: ATS = American Thoracic Society; CI = confidence interval; ITS = Intermountain Thoracic Society; PFT = pulmonary function test; TLC = total lung capacity

Current recommendations from the American Thoracic Society (ATS) are that the severity of airflow obstruction should be based on the percent predicted of the measured FEV$_1$. Previous recommendations by the Intermountain Thoracic Society (ITS) based grading of obstruction on the FEV$_1$/FVC ratio$^2$ (Table 1). This method is dependent on the expiratory time, so that the longer the patient exhaltes, the greater will be the value of the FVC. No recommendations from the ATS currently exist for the grading of obstruction in the presence of an additional restriction. Because a restrictive process is associated with reductions in both FEV$_1$ and FVC, in the presence of additional obstruction the grading of the degree of obstruction on FEV$_1$ alone may result in a significant overemphasis on the grading of the obstruction. In pulmonary function tests (PFTs) with combined obstruction and restriction, using the ATS approach will result in all the reduction in FEV$_1$ being attributed to the obstruction.

Two basic types of PFT abnormalities can be defined by pulmonary function testing, namely, obstructive and restrictive patterns. Obstruction is de-
Grading the Severity of Obstruction

<table>
<thead>
<tr>
<th>Grading System</th>
<th>Disease Severity</th>
<th>Values</th>
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</thead>
<tbody>
<tr>
<td>ATS</td>
<td>Mild</td>
<td>≥ 70%–100% predicted*</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>≥ 60%–70% predicted*</td>
</tr>
<tr>
<td></td>
<td>Moderately severe</td>
<td>≥ 50%–60% predicted†</td>
</tr>
<tr>
<td></td>
<td>Severe</td>
<td>≥ 34%–50% predicted†</td>
</tr>
<tr>
<td></td>
<td>Very severe</td>
<td>&lt; 34% predicted†</td>
</tr>
<tr>
<td>ITS‡ Mild obstruction</td>
<td>≥ 1 and &lt; 2 CIs*</td>
<td></td>
</tr>
<tr>
<td>Moderate obstruction</td>
<td>≥ 2 and &lt; 4 CIs*</td>
<td></td>
</tr>
<tr>
<td>Severe obstruction</td>
<td>≥ 4 CIs†</td>
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</table>

*Nonsevere group.
†Severe group.
‡CI = 1.65 SEE for one-tailed test or 1.96 SEE for two-tailed test.

Materials and Methods

The Cedars Sinai Medical Center is a tertiary referral center serving predominantly Medicare, health maintenance organizations, Medi-Cal, and privately funded patients. The studies were performed in a fully equipped (SensorMedics Corporation; Yorba Linda, CA) pulmonary function laboratory. The equipment remained unchanged for the study period, the equipment and techniques conformed to ATS criteria.

A retrospective analysis was performed on a computerized database of all PFTs meeting the ATS criteria that had been performed between April 1, 1978, and June 8, 1999, on patients ≥ 18 years of age. Demographic data were obtained in addition to prebronchodilator FEV1, FVC, FEV1/FVC ratio, and TLC parameters. Predicted values for these PFT parameters were based on the data of Crapo and coworkers.4,5 These data sets provided the lower limits of normal based on the 95th percentile, thus allowing the calculation of the 95% CIs.

Obstruction was determined to be present if the FEV1/FVC ratio was significantly reduced (ie, greater than one CI below the predicted value). Restriction was deemed to be present when the TLC was greater than 1 CI below the predicted value. Hyperinflation was present where the TLC was > 1 CI above the predicted value. In the PFT results that exhibited evidence of obstruction, the ATS and ITS grading systems were used to divide the PFTs into the following two categories of severity: severe grades of obstruction; and all other severity grades (ie, normal, mild, moderate) [Table 1].

The distribution of the severity of obstruction using the ATS and ITS methods was then compared between PFTs with TLC values judged to be below, above, or within the normal range.

Data and Statistical Analysis

Pulmonary function data that previously had been collected were analyzed using a database (ACCESS; Microsoft Corporation; Redmond, WA). The results of the database queries were exported to a spreadsheet (EXCEL; Microsoft Corporation) and subsequently to a software package (SIGMASTAT; Jandel Scientific Software; San Rafael, CA) for further analysis.

The distribution of the pattern of severity grading (using the two categories derived from both the ATS and ITS grading systems) was compared. An analysis of the severity distribution was made with the χ2 test. The distributions of the following three patterns of severity grading were compared: (1) the ATS grading being more severe than the ITS; (2) ATS and ITS grading

<table>
<thead>
<tr>
<th>Grading Non-severe Group</th>
<th>Severe Group</th>
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<tbody>
<tr>
<td>Obstructive defect with increased TLC (552 PFTs)</td>
<td>1366</td>
</tr>
<tr>
<td>ITS</td>
<td>328</td>
</tr>
<tr>
<td>ATS</td>
<td>219</td>
</tr>
<tr>
<td>Obstructive defect with normal TLC (1890 PFTs)</td>
<td>1636</td>
</tr>
<tr>
<td>ITS</td>
<td>1636</td>
</tr>
<tr>
<td>ATS</td>
<td>459</td>
</tr>
<tr>
<td>Combined obstructive and restrictive defect (147 PFTs)</td>
<td>143</td>
</tr>
<tr>
<td>ITS</td>
<td>143</td>
</tr>
<tr>
<td>ATS</td>
<td>14</td>
</tr>
<tr>
<td>PRCI</td>
<td>91</td>
</tr>
</tbody>
</table>

*PRCI = proposed CI-based grading system (grades of obstruction: mild, > 1 and ≤ 1.5 CIs; moderate, > 1.5 and ≤ 2 CIs; severe, > 2 CIs).
having equal severity; and (3) the ITS grading being more severe than the ATS grading. The severity grading differences were compared between PFT results with a normal TLC, restriction, and hyperinflation. A p value of < 0.05 was considered to be significant.

RESULTS

Database analysis revealed 21,499 PFTs, with 50.5% performed on men and 49.5% on women. The mean age in men was 59.5 years, and in women it was 59.2 years. The mean height in men was 68.3 inches, and in women it was 62.9 inches.

TLC was measured in 5,962 of the above PFTs (both by means of helium dilution and plethysmography). Of these studies, the results of 2,619 PFTs (43.9%) gave evidence of obstruction, of which 512 (19.5%) were graded as revealing severe obstruction using the ITS grading system, with the remainder graded as revealing either mild or moderate obstruction. In contrast, using the ATS grading criteria on the same data that had exhibited obstruction, a far higher percentage (51.2%; 1,341 PFTs) were graded as being severe (ie, moderately severe, severe, or very severe), while 219 were in the alternative category (ie, normal, mild, or moderate). In the group with normal TLC values, 254 PFTs (13.4%) were graded as having severe obstruction using the ITS grading system, and 1,636 PFTs were graded as having either mild or moderate obstruction. In contrast, using the ATS grading criteria on the same group, 845 PFTs (44.7%) were graded as being severe (ie, moderately severe, severe, or very severe), while 1,045 were in the alternative category (ie, normal, mild, or moderate) [Table 2].

In the combined group (ie, reduced TLC in the presence of obstruction), 4 PFTs (2.7%) were graded as showing severe obstruction using the ITS grading system, and 143 were graded as having either mild or moderate obstruction. In contrast, using the ATS grading criteria on the same group of obstructed...
pulmonary functions, 133 PFTs (90%) were graded as being severe (ie, moderately severe, severe, or very severe), with only 14 PFTs in the alternative category (ie, normal, mild, moderate) [Table 2].

Analyzing the distribution in the discordant grading between the ATS and ITS grading systems revealed distinct differences. There was a significantly higher frequency of the ATS grading being more severe than the ITS grading for obstruction in the presence of restriction than in either the normal or hyperinflated group. The number of PFTs in which the ATS system graded PFTs more severely than the ITS system was 595 in the normal TLC group and 129 in the restricted group, which result was significantly different from those of the grading distribution of PFTs in which the ITS system grading was found to be more severe than that of the ATS system (normal TLC, 4 PFTs; restricted TLC, 0 PFTs; p < 0.01). The number of PFTs in which the ATS system graded PFTs more severely than the ITS system was 113 in the hyperinflated group and 129 in the restricted group, which was significantly different than the distribution of PFTs in which the ITS system was more severe than the ATS system (hyperinflated TLC, 4 PFTs; restricted TLC, 0 PFTs; p < 0.01). This relationship in the distribution of the two categories of severity in the normal, hyperinflated, and restrictive groups is graphically depicted in Figure 1.

An alternative to using the ITS FEV₁/FVC ratio CI breakpoints would be to use a system based on a different ratio of the CIs. The multiples of CI above which severe obstruction would be present would be 2 (as compared to 4 in the ITS FEV₁/FVC ratio system). The proposed grading system would be as follows: mild obstruction, > 1 and ≤ 1.5 CIs; moderate obstruction, > 1.5 and ≤ 2 CIs; and severe obstruction, > 2 CIs. Using this system in the group with PFT results indicating obstruction with restriction (ie, combined defects) would have resulted in 56 studies (38.1%) being graded as having severe obstruction, with the remainder (ie, 91 studies) being graded as having either mild or moderate obstruction. In contrast, as reported earlier, using the ATS grading criteria on the same group of obstructed pulmonary functions would have yielded a far greater percentage being graded as severe (90%) [Table 2]. This approach would also lead to a more balanced severity difference distribution in the group of PFTs with results indicating obstruction and concurrent restriction (Fig 1).

**DISCUSSION**

Pulmonary function tests have become a part of routine health examinations, providing objective and quantifiable measures of lung function. They are used to evaluate and monitor diseases that affect heart and lung function, to monitor the effects of environmental, occupational, and drug exposures, and to assess the risks of surgery.

The interpretation of lung function testing is based on the relationship of the measured values to the reference values. PFTs may be used to assess the causes of dyspnea and to address major issues in clinical case management including describing dysfunction and assessing its severity. Severity assessment ideally is derived from studies that relate PFT values to independent indexes of performance, such as inability to work and function in daily life, morbidity, and prognosis.

The ITS (in 1974) and subsequently the ATS undertook the responsibility of standardizing pulmonary function laboratory procedures and establishing reference values. Reference values can vary widely, so it is important to select reference values that are representative of the population being studied.

The adult reference equations that are used most commonly by pulmonary function laboratories in the United States are those of Crapo et al., Morris et al., Knudson et al., and Enright.

The criteria that were used for selecting reference equations include population samples with wide ranges of height and weight, never smokers, and absence of heart or lung disease or the presence of chronic respiratory symptoms.

Both FEV₁ and FEV₁/FVC ratio have been found to be independent predictors of both all-cause and respiratory mortality. Our study found that using either FEV₁ as a percentage of predicted values or the FEV₁/FVC ratio resulted in a similar relative frequency distribution of severity in obstructed PFT results with either concurrent hyperinflation or normal TLC (Fig 1). However, in PFTs exhibiting an obstructive pattern together with concurrent restriction, the use of FEV₁ as a percentage of predicted values to grade obstruction resulted in a far greater grading of severity than using the FEV₁/FVC ratio (using CI multiples as described in the ITS recommendations). Use of the intermediate CI ranges for FEV₁/FVC ratio that we propose would yield a severity grading for obstruction in between the ATS and ITS criteria for that cohort of patients exhibiting combined obstructive and restrictive ventilatory patterns. Another reason to propose this modification in the CI range modification is to account for the fact that restriction often produces a supernormal FEV₁/FVC ratio as a consequence of higher elastic recoil. Grading the severity of obstruction has important implications for disability rating, which has effects on the patients’ perceptions of their disease. A different severity rating could have implications for therapeutic intervention.
In summary, the severity of obstruction in patients with additional restriction is overestimated if it is based on the percent predicted FEV\textsubscript{1} alone. It is therefore suggested that an alternative grading system be used only in this cohort of studies (which would be based on multiples of the FEV\textsubscript{1}/FVC ratio CIs). This would avoid the problem of overestimating the degree of obstruction in the presence of a concurrent restrictive ventilatory pattern and would serve to standardize the interpretation of such test results across different laboratories.

REFERENCES
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