The Clinical Evaluation for Diagnosing Obstructive Airways Disease in High-Risk Patients*


Objective: We measured the ability of the medical history, physical examination, and peak flowmeter in diagnosing any degree of obstructive Airways Disease (OAD). Design: Prospective comparison of historical and physical findings with independently measured spirometry. Setting: University outpatient clinic. Patients: Ninety-two adult consecutive outpatient volunteers with a self-reported history of smoking, asthma, chronic bronchitis, or emphysema. Measurements: All subjects completed a pulmonary history questionnaire and received peak flow (PF) and spirometric testing. The subjects were independently examined for 12 pulmonary physical signs by four internists blinded to all other results. Multivariable analysis was used to create a diagnostic model to predict OAD as diagnosed by spirometry (FEV1 < 80 percent of predicted not secondary to restrictive disease, or FEV1/FVC less than 0.7).

Results: The best model diagnosed OAD when any of three variables were present—a history of smoking more than 30 pack-years, diminished breath sounds, or peak flow less than 350 L/min. This model had a sensitivity of 98 percent and specificity of 46 percent. In addition, the model detected all subjects with probable restrictive lung disease. Thirty-one percent of subjects had none of these variables and were at very low (3 percent) risk of OAD. Fifty percent of subjects with one or more abnormal variables had OAD.

Conclusions: The history, physical examination, and peak flowmeter can be used to screen high-risk patients for OAD. Using this diagnostic model, 31 percent of subjects could be classified at very low risk of OAD while half of those referred for spirometry would have abnormal results.

COPD=chronic obstructive pulmonary disease; FEV1=forced expiratory volume in 1 s; FVC=forced vital capacity; OAD=obstructive Airways disease, including asthma; PF=peak flow; PMI=point of maximal impulse; ROC=receiver operating characteristic

Key words: emphysema; obstructive Airways disease; peak flowmeter; physical diagnosis; recursive partitioning; screening; spirometry

Obstructive Airways Disease (OAD), including chronic obstructive pulmonary disease (COPD) and asthma, are common and morbid illnesses. COPD is the fifth most common cause of death and the second leading cause of disability in the United States. However, only 19 percent of patients with COPD in the Rand Health Insurance Study had had their conditions previously diagnosed by a physician. Once mild Airways obstruction is present (forced expiratory volume in 1 s [FEV1] < 80 percent of predicted or FEV1/FVC ratio < 0.7), there is an increased decline of lung function. Asthma occurs in approximately 5 percent of the US population. The mortality from asthma is increasing and may be underreported. Spirometry can identify patients with mild OAD, but it is inefficient to refer all at risk patients for spirometry. The identification of clinical parameters to stratify patients' risk of OAD would reduce the number of patients who would have to be referred and charged for spirometry to diagnose mild OAD.

We previously reported the ability of the medical history, physical examination, and peak flowmeter to diagnose moderate to severe OAD. The purpose of this study was to quantify the ability of the medical history, pulmonary physical examination, and peak flow (PF) measurement to identify any degree of OAD in patients at risk of OAD because of smoking or a self-reported previous diagnosis of chronic bronchitis, emphysema, or asthma.

Methods

Study Population

Subjects were recruited by notices posted in the outpatient clinics of the University of Colorado Health Sciences Center and...
the Denver Veterans Affairs Medical Center. We recruited outpatients to facilitate generalizing our results to community practice. Inclusion criteria were current or former smoking over the age of 40 years or a self-reported diagnosis of chronic bronchitis, emphysema, or asthma. Consecutive subjects fulfilling inclusion criteria were studied. The University of Colorado Health Sciences Center Institutional Review Board approved the protocol and all subjects gave written, informed consent.

Protocol

The subject's medical history was obtained by completing a self-administered questionnaire, as previously described. The questionnaire sought possible respiratory symptoms and risk factors that were identified in previous studies.

All subjects underwent four independent physical examinations by four board-certified internists blinded to the patients' histories and spirometric results. The examinations sought 12 clinical signs of airway obstruction. Six of the signs were qualitative variables: general appearance, percussion note, cardiac dullness, wheezes, decreased breath sounds, and the examiner's final opinion. These variables were recorded as definitely abnormal, probably abnormal, probably normal, or definitely normal. The definitions were standardized by examining three model patients before the study. The remaining variables (ruler sign, Snider test, forced expiratory time [FET]), magnitude of expansion of chest circumference, and magnitude of diaphragmatic excursion) were recorded in absolute numbers. The point of maximal impulse (PMI) was recorded as thoracic, epigastric, or nonpalpable.

Each subject underwent spirometric testing using the American Thoracic Society guidelines on a Spirometer (Spirometrics SMI III). Obstructive airways disease was defined as either an FEV1 less than 80 percent of predicted normal in the absence of restrictive disease (FVC <80 percent of predicted with FEV1/FVC ratio >0.8) or an FEV1/FVC ratio less than 0.7. The equations of Crapo et al were used to predict normality. The predicted normals were adjusted because of Denver's elevation. The PF was the best of three readings measured on a peak flowmeter (Assess). Statistical Analysis

Receiver operator characteristic (ROC) tables were made for all clinical findings. The findings were then dichotomized using the cutoff that gave the highest sum of sensitivity and specificity. Physical examination observations from each physician were pooled. The unit of analysis was the physical examination; thus, there were four observations per patient. The kappa statistic for multiple raters measured interphysician agreement for the physical examination variables after they were dichotomized about their best cutoff.

All variables with univariate p <0.05 were candidates for multivariable analysis except previous diagnosis of pulmonary disease, medicines used to treat OAD (inhalers, theophylline, steroids, oxygen), and the Snider test. These historical questions were deleted to allow this study to generalize to populations with less previous exposure to physicians. The Snider test was deleted because the odor of multiple burnt matches irritated some patients and others had difficulty in blowing with their mouths opened wide.

The multivariable analysis was done with a modified recursive partitioning analysis. In recursive partitioning analysis, a decision tree is made with a stepwise selection of the strongest variable. This variable is the one that has the lowest "dispersity index," which is the sum of the false-negatives and false-positives. To increase the sensitivity of the analysis, false-negatives were weighted by the ratio of normal to diseased subjects. In this study the weight was 1.8. Variables were selected as long as they reduced the weighted dispersity index for all four physicians, and was stopped when the model defined a normal population with a 5 percent or less chance of OAD (5 percent was a priori chosen as a threshold that adequately rules out OAD). Additionally, each new two-by-two table formed by adding a new variable for the remaining subjects had a χ2 (or two-tailed Fisher's exact test where appropriate) with p <0.05. To create an easily remembered and simple decision tree, the tree was allowed to branch in only one direction. The accuracy, sensitivity, specificity, and area under the ROC curve was then calculated for each physician using the final model.

Analyses were performed with a standard statistical software package. The programs for the area under the ROC curve, kappa, and recursive partitioning were written in a statistical package (SAS) by one of us (R.G.B.). These programs were validated by replicating sample data sets.

RESULTS

Ninety-two subjects were studied. One examiner could not attend one session (20 subjects) and five examinations were excluded because the physician had prior knowledge of the subject's health, resulting in 343 evaluable subject-physician interactions. Fifty-three percent of subjects were men with a mean age of 56 years who had smoked between 25 and 30 pack-years. Thirty-two subjects (35 percent) had OAD (FEV1 <0.8 of predicted with FVC <0.8 of predicted or FEV1/FVC ratio <0.7) by spirometry. Fifteen of these 32 subjects had an FEV1 less than 60 percent of predicted normal or an FEV1/FVC ratio <0.6. Fourteen of the 32 subjects had chronic bronchitis (phlegm for most mornings of three months during each of the past 2 years). Four patients (4 percent) had probable restrictive lung disease. Three of these four patients had an FEV1 less than 80 percent of predicted and were labeled as nonobstructed and grouped with the normal patients.

Univariate analysis of the medical history as obtained by the medical questionnaire yielded eight responses that were statistically significant in predicting OAD. These are listed in Table 1, ranking the variable with the highest sum of sensitivity plus specificity first. The univariate results of the physical examination are in Table 2, listed in the order that they were measured by the physicians. All physical examination measures were significant except for the ruler sign. We found the best cutoff for the mean FET was ≥4 s, although the FET has been reported to perform best at a cutoff of ≥6 s. At ≥6 s, its sensitivity was 40 percent and specificity was 77 percent. The PF had a sensitivity of 63 percent and specificity of 85 percent using a best cutoff of less than 350 L/min.

The index of interrater reliability, kappa, ranged from 0.05 for the assessment of diaphragmatic excursion to 0.53 for the physicians' final opinion after the blinded physical examination (Table 2). Referring to the scale of Landis and Koch as reported by Kramer and Feinstein, the agreement was moder-
ate (kappa, 0.41 to 0.60) for the physicians’ final opinions, the assessments of cardiac dullness, and the presence of wheezes.

Recursive partitioning analysis identified three variables that significantly contributed to the diagnosis of OAD. In order of their selection into the model, the variables were PF less than 350 L/min, diminished breath sounds, and 30 pack-years or more of smoking. Smoking history was included although it did not significantly add to one physician’s model that had already excluded OAD using the first two variables. The performance of the model is described in Table 3. Defining abnormal as the presence of any of these variables, OAD was diagnosed with a sensitivity of 98 percent, specificity of 46 percent, and accuracy of 65 percent. The model’s area under the ROC curve was 0.871 ± 0.021. Ninety-six percent of the subjects with all three variables present had OAD.

Fifty percent of subjects with one or more variables had OAD by spirometry. Thirty-one percent of subjects had none of these variables and had a 3 percent chance of OAD. The 3 percent false-negative rate was because of one subject with an FEV₁ that was 78 percent of predicted who was thought to have normal breath sounds by all three physicians who examined him. The model was abnormal in all examinations of the four patients with restrictive lung disease. The model detected 94 percent of subjects who previously had not been diagnosed as having OAD. Including self-reported use, respiratory medications did not improve the model.

**DISCUSSION**

In this study of high-risk subjects, OAD could be identified with 98 percent sensitivity if subjects either smoked more than 30 pack-years, or had diminished

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**Table 1—Univariate Historical Predictors of OAD* in 92 Subjects**

<table>
<thead>
<tr>
<th>Cutoff</th>
<th>Sensitivity, %</th>
<th>Specificity, %</th>
<th>Positive (Prevalence=35%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous diagnosis of COPD†</td>
<td>yes vs no</td>
<td>59</td>
<td>78</td>
</tr>
<tr>
<td>Smoke,† pack-yr</td>
<td>≥30</td>
<td>60</td>
<td>77</td>
</tr>
<tr>
<td>Age,† yr</td>
<td>≥50 yr</td>
<td>84</td>
<td>44</td>
</tr>
<tr>
<td>DSSS‡</td>
<td>≥4</td>
<td>47</td>
<td>78</td>
</tr>
<tr>
<td>Steroid use‡</td>
<td>Yes vs no‡</td>
<td>31</td>
<td>92</td>
</tr>
<tr>
<td>Theophylline use‡</td>
<td>Yes vs no‡</td>
<td>47</td>
<td>73</td>
</tr>
<tr>
<td>Previous diagnosis of asthma†</td>
<td>Yes vs no</td>
<td>35</td>
<td>83</td>
</tr>
<tr>
<td>Inhaler use‡</td>
<td>Yes vs no‡</td>
<td>19</td>
<td>95</td>
</tr>
<tr>
<td>Wheezes other than during a cold</td>
<td>Yes vs no</td>
<td>53</td>
<td>60</td>
</tr>
<tr>
<td>Home O₂‡</td>
<td>Yes vs no‡</td>
<td>13</td>
<td>97</td>
</tr>
<tr>
<td>Phlegm production</td>
<td>&gt;1 tbsp/d when present</td>
<td>33</td>
<td>72</td>
</tr>
<tr>
<td>Ever short of breath</td>
<td>Yes vs no</td>
<td>78</td>
<td>20</td>
</tr>
</tbody>
</table>

*Obstructive airway disease (FEV₁ <80% of predicted without restrictive disease, or FEV₁/FVC<0.7).
†p<0.05.
‡DSSS=dyspnea severity scale score. A score of 4 is shortness of breath when bathing or dressing.
§The subject responded yes vs no or no response. Additional insignificant variables were sex, ethnic group, self-report of occupational exposure, income, education.

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**Table 2—Significant Univariate Physical Examination Predictors of OAD* in 343 Examinations**

<table>
<thead>
<tr>
<th>Cutoff</th>
<th>Kappa</th>
<th>Sensitivity, %</th>
<th>Specificity, %</th>
<th>Predictive Value, %</th>
<th>Positive (Prevalence=35%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial impression</td>
<td>...†</td>
<td>0.50</td>
<td>41</td>
<td>81</td>
<td>54</td>
</tr>
<tr>
<td>Chest expansion, cm</td>
<td>≥4</td>
<td>0.33</td>
<td>66</td>
<td>50</td>
<td>42</td>
</tr>
<tr>
<td>Diaphragm excursion, cm</td>
<td>≥4</td>
<td>0.05</td>
<td>37</td>
<td>74</td>
<td>44</td>
</tr>
<tr>
<td>Auscultory percussion</td>
<td>...†</td>
<td>0.37</td>
<td>42</td>
<td>86</td>
<td>63</td>
</tr>
<tr>
<td>Cardiac dullness</td>
<td>...†</td>
<td>0.47</td>
<td>26</td>
<td>96</td>
<td>80</td>
</tr>
<tr>
<td>Wheezes present</td>
<td>...†</td>
<td>0.50</td>
<td>6</td>
<td>99</td>
<td>88</td>
</tr>
<tr>
<td>Breath sounds reduced</td>
<td>...†</td>
<td>0.58</td>
<td>57</td>
<td>88</td>
<td>62</td>
</tr>
<tr>
<td>FET mean, s</td>
<td>≥4 s</td>
<td>0.11</td>
<td>77</td>
<td>49</td>
<td>45</td>
</tr>
<tr>
<td>PMI</td>
<td>Abdominal</td>
<td>0.30</td>
<td>15</td>
<td>99</td>
<td>86</td>
</tr>
<tr>
<td>Final opinion</td>
<td>...†</td>
<td>0.53</td>
<td>55</td>
<td>81</td>
<td>61</td>
</tr>
</tbody>
</table>

*Obstructive airway disease (FEV₁ <80% of predicted without restrictive disease or FEV₁/FVC<0.7). The ruler sign was insignificant.
†Definitely or possibly abnormal vs possibly normal or normal.

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Abnormal Findings

Table 3—Predicting OAD* in 342 Examinations With Clinical Findings

<table>
<thead>
<tr>
<th>No. of Abnormal Findings</th>
<th>No. (%) of Examinations</th>
<th>No. (%) of Examinations With OAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (normal)</td>
<td>105 (31)</td>
<td>3 (3)</td>
</tr>
<tr>
<td>1</td>
<td>125 (37)</td>
<td>39 (31)</td>
</tr>
<tr>
<td>2</td>
<td>87 (25)</td>
<td>56 (64)</td>
</tr>
<tr>
<td>3</td>
<td>23 (7)</td>
<td>24 (96)</td>
</tr>
</tbody>
</table>

*Obstructive airways disease (FEV<1:<80% of predicted without restrictive disease or FEV1/FVC<0.7).
†The score is the number of the following abnormal variables that a subject had: peak flow less than 350 L/min, definitely or possibly diminished breath sounds, 30 pack-years or more of smoking. There were 543 examinations; one physician did not record an impression of breath sounds on one patient.

breath sounds, or had a peak flow rate of less than 350 L/min. Subjects with none of these variables had only a 3 percent chance of OAD.

Only one other study has combined medical history and physical examination variables with multivariable analysis in the diagnosis of OAD.27 Holleman et al27 successfully used smoking, self-report of wheezes, and either the PF or auscultated wheezing to diagnose OAD in male veterans in a prospective clinic. Our results for auscultated wheezes were very similar; however, there may be several reasons we found diminished breath sounds performed better. First, in the study of Holleman et al,27 breath sounds were recorded only for the last one third of the study. They were twice as sensitive as wheezes, although less specific. Second, our multivariable analysis emphasized variables with high sensitivity in order to “rule-out” OAD. Lastly, our physicians were trained using model patients before the study began. Other univariate studies have also found breath sounds to perform well.28-30 In a blinded study of 14 physical examination variables, Schneider and Anderson11 found diminished breath sounds to be the best predictor of airway obstruction, although the examining physicians predicted it would be one of the weaker signs. Other studies have successfully used breath sounds as part of a composite clinical evaluation to diagnose airways obstruction.31,32

Our model was more predictive of OAD than the subjects’ previous medical care. The sensitivity of the model in predicting OAD was 98 percent and the sensitivity of the subject’s self-report of either chronic bronchitis, emphysema, or asthma was 61 percent. Surprisingly, 20 percent of the subjects with a self-reported diagnosis had normal results of spirometry. Although one half of these subjects had symptomatic criteria for chronic bronchitis without obstruction, the remaining half seemed to report an erroneous diagnosis. Although our model was improved by using self-reported diagnoses, a priori, we had decided not to use previous diagnoses because these results might not generalize to patients who have not volunteered to participate in a study or who have had less previous medical care.

There are several limitations of our study. First, the study design required the physicians to make their final opinion without knowledge of the subjects’ histories and without feedback about the utility of the physical examination maneuvers. Without this information, the physician’s final opinions almost entered the model in place of diminished breath sounds. With feedback, the accuracy of the overall model may have improved. This study should be replicated at another site, preferably with enough subjects to verify that the low-risk subjects truly had a less than 5 percent chance of OAD. The study size and the spirometric definition of OAD prevent subanalyses of whether emphysema, chronic bronchitis, and asthma might have individualized clinical predictors.

In summary, this study suggests the medical history, physical examination, and peak flowmeter can rule out OAD in one third of high-risk patients. Patients subsequently referred for spirometry will more likely have abnormal results. The best variables for diagnosing OAD were reduced PF rate, the quality of breath sounds, and smoking for at least 30 pack-years. These results, if validated, can direct further testing.

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