The Relationship Between Pulmonary Function and Dyspnea in Obstructive Lung Disease*

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Increased importance is now being placed on evaluating dyspnea in patients with obstructive lung disease (OLD). We measured breathlessness at rest, using a Borg scale dyspnea index (BSDI) before and after bronchodilator (albuterol [salbutamol] 200µg) in 93 patients with OLD drawn from a larger population undergoing routine spirometry. The median BSDI declined from 3 to 1 before and after bronchodilator, suggesting improvement in dyspnea. However, there was no correlation between initial or postbronchodilator spirometry and BSDI. The change in FEV₁, similarly did not correlate with the change in BSDI ($r = 0.05$). A large bronchodilator response was usually associated with improvement in dyspnea, but the converse was not observed. Thus, of ten patients with an improvement in BSDI of more than two categories, six had a change in FEV₁ of 0.1 L or less after bronchodilator. Analyzing a subgroup of 65 dyspneic patients with an initial BSDI of 2 or more revealed the following response groups: those with either a bronchodilator or dyspnea response alone, both together, or neither. Twenty-eight patients (43 percent) responded both subjectively and objectively. Eleven (17 percent) had a bronchodilator response only, 17 (26 percent) had a dyspnea response only, while nine (14 percent) had neither measurable response. We conclude that dyspnea is poorly correlated with results of routine spirometry in patients with OLD. The use of dyspnea ratings may yield information about bronchodilator responsiveness not appreciated by spirometry alone. (Chest 1989; 96:1247-51)

OLD = obstructive lung disease; BSDI = Borg scale dyspnea index

Traditionally, pulmonary physicians have relied on objective measures of lung function to assess disease severity and response to therapy in patients with obstructive lung disease (OLD). Recently, there has been increased interest in the use of subjective measures of dyspnea in the assessment of exercise tolerance and bronchodilator efficacy in patients with asthma and chronic obstructive pulmonary disease (COPD).¹,⁶

Intuitively, it would appear that those patients with the most severe airway obstruction should be the most dyspneic. However, clinical experience teaches that this is not always the case. Some patients with severe OLD are minimally symptomatic, while others with little objective dysfunction are very dyspneic. Thus, the relationship between airway obstruction and dyspnea is complex, and it is unclear to what extent measures of each correlate in patients with OLD.

Several previous studies have investigated the cor

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Materials and Methods

This study involved sequential outpatients who were referred to the Sir Mortimer B. Davis—Jewish General Hospital for routine pulmonary function testing between March 1 and Oct 1, 1987. Those who were unable to perform spirometry according to the protocol, or who had taken inhaled ß-agonist within 1 h of arrival in the laboratory were excluded. One hundred seventy-four patients represented the initial study population screened. They included those with known asthma, COPD, or restrictive lung disease who were being assessed in follow-up as well as newly diagnosed cases. Other individuals were being evaluated for cough, dyspnea, or were having preoperative testing.
Table 1—Spirometry Results (Mean ± SD) Before and After Bronchodilator (n = 93)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before Bronchodilator</th>
<th>After Bronchodilator</th>
<th>Percent Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV₁, L</td>
<td>1.19 ± 0.43</td>
<td>1.42 ± 0.52</td>
<td>20.8 ± 17.5</td>
</tr>
<tr>
<td>FVC, L</td>
<td>2.12 ± 0.54</td>
<td>2.45 ± 0.71</td>
<td>16.8 ± 13.9</td>
</tr>
<tr>
<td>FEF₉₀₋₁₂₀ L/s</td>
<td>0.63 ± 0.32</td>
<td>0.81 ± 0.46</td>
<td>26.9 ± 31.2</td>
</tr>
</tbody>
</table>

Correlation coefficients were calculated for data before and after bronchodilator. The change in pulmonary function vs. the change in dyspnea was similarly examined. The Wilcoxon signed rank test was used in comparing before and after bronchodilator dyspnea scores. The nonparametric tests were chosen for data analysis to minimize assumptions about distribution of data. However, applying the parametric tests for normally distributed data did not alter results. A p value of less than 0.05 was considered statistically significant.

RESULTS

Ninety-three (41 male and 52 female) of 174 initially screened subjects conformed to the aforementioned definition of OLD and are included in the subsequent analysis. The mean age of these patients was 68 ± 11 years. The results of spirometry are shown in Table 1.

The correlation between pulmonary function values and dyspnea using either FEV₁, FVC, or FEF₉₀₋₁₂₀ was similar. Accordingly, only the former is presented below, although the results were consistent for all three parameters. There was no correlation (r = −0.04) between prebronchodilator dyspnea as measured by the BSDI and FEV₁ (Fig 2).

Following albuterol the mean percentage of change in FEV₁ was 20.8, but there was a considerable range of responses (−4.8 percent to +76.9 percent). As a group these subjects demonstrated a reduction in dyspnea after bronchodilator. The median BSDI was 3 and 1 before and after bronchodilator, respectively. However, there was no correlation (r = −0.08) between BSDI and FEV₁ measured after bronchodilator (Fig 3). As

Statistical Analysis

The degree of relationship between pulmonary function and dyspnea score was established using Spearman rank correlations.

Figure 1. Modified Borg scale used to record dyspnea.

The experimental protocol was as follows. Each subject was asked to rest comfortably in a chair for 10 to 15 minutes after arrival in the pulmonary function laboratory. They were then instructed to record the degree of dyspnea felt at that moment, and described as "shortness of breath," by making a mark on a vertical scale. This consisted of a modified Borg category scale that ranged from 0 to 10 and included verbal descriptors (Fig 1). The number nearest the mark made by the subject was referred to as the Borg Scale Dyspnea Index (BSDI). Next, the patient performed successive forced expiratory maneuvers using a spirometer (Vitalograph model S; Lenexa, Kansas). FEV₁, FVC, and FEF₉₀₋₁₂₀ were calculated as described below. The patient then received two puffs (200 µg) of salbutamol (Ventolin, Glaxo, Canada) delivered by metered dose inhaler using the closed mouth technique. Twenty minutes later the dyspnea index and spirometry were repeated in identical fashion.

Spirometry was performed according to the general guidelines of the American Thoracic Society. Three to five forced expiratory maneuvers were obtained before and after administration of the bronchodilator. The "best test" curve was defined as that which produced the largest FVC and FEV₁, and which was reproducible to within 10 percent on at least two determinations. The FEF₉₀₋₁₂₀ was calculated from the best curve. The largest FEV₁ and FVC were separately obtained from among the reproducible curves representing the best effort.

Predicted normal spirometric values were those of Crapo et al. Obstructive lung disease was said to be present when prebronchodilator FEV₁ was 70 percent or less of predicted and FEV₁/FVC was 70 percent or less.

A bronchodilator response was defined as an improvement in FEV₁ of at least 15 percent after albuterol. A dyspnea response was arbitrarily defined as a reduction in the BSDI by at least one full category after bronchodilator. For the purpose of the present study, no effort was made to distinguish between those individuals with asthma as opposed to COPD, and the term OLD is used to encompass both groups of patients.
seen in Figure 4, there was also no correlation \( r = 0.05 \) between the change in \( FEV_1 \) and change in the measure of dyspnea after albuterol. When the above calculations were repeated with \( FEV_1 \) expressed as percent predicted, it still failed to correlate significantly with the corresponding measure of dyspnea.

Those individuals with the greatest dyspnea responses had not necessarily achieved large bronchodilator responses. Thus, of ten patients with an improvement in BSDI of more than two categories, six had an \( FEV_1 \) response of 0.1 L or less. Conversely, however, a very large bronchodilator response was usually associated with improvement in dyspnea. Eleven patients had an improvement in \( FEV_1 \) of 0.5 L or greater. Of these, seven had a prebronchodilator BSDI of 2 or more indicating at least “slight” dyspnea at rest. While dyspnea was eliminated in none, six subjects displayed a dyspnea response after bronchodilator.

Next, we examined the occurrence of subjective and objective responses in individual subjects. Since some patients were not dyspneic before bronchodilator, they were incapable of reporting subjective improvement after albuterol. Hence, we analyzed a subgroup of 65 patients who were dyspneic at the time of testing as defined by a prebronchodilator BSDI of 2 or more. Thirty-nine (60 percent) of 65 dyspneic patients responded to bronchodilator as measured by a change in \( FEV_1 \). Forty-five (69 percent) demonstrated a dyspnea response evidenced by a reduction in the BSDI by at least one category after bronchodilator. Thus, the overall response rate was similar whether measured either subjectively or objectively.

Table 2 illustrates the number of patients who showed either a bronchodilator or dyspnea response alone, both together, or neither within the subgroup of 65 dyspneic individuals with OLD. By considering change in dyspnea as well as improvement in pulmonary function as end points, four outcome groups were obtained. The most frequent pattern observed was improvement in both subjective and objective parameters. Only 14 percent of individuals showed neither a significant bronchodilator nor dyspnea response.

**DISCUSSION**

We found a poor correlation between \( FEV_1 \), \( FVC \), and \( FEF_{25-75} \) measured by routine spirometry and dyspnea assessed by a Borg scale in patients with OLD. Although dyspnea scores improved after albuterol, the changes in dyspnea did not correlate well with improvement in the above measures of pulmonary function. A very large objective response to albuterol was consistently associated with improvement in dyspnea. However, those with large subjective responses often had insignificant changes in \( FEV_1 \) after bronchodilator. These findings do not mean that dyspnea and underlying airway obstruction are unrelated. Rather they suggest that the relationship between airway obstruction and dyspnea is not simple. Breathlessness probably depends on a complex interplay of mechanical, experiential, and other factors. 12

Our results support the findings of several previous studies. Although McGavin et al. showed a significant correlation between exercise performance, as measured by the 12-minute walk and both \( FEV_1 \) and FVC,
there was no significant correlation between either of
these indices of airway obstruction and subjective
assessments of dyspnea. Burrows et al.\textsuperscript{13} found that
FEV\textsubscript{1}, especially when expressed as a percentage of
FVC, was the pulmonary function variable that best
correlated with a history of dyspnea in patients with
OLD. However, the relationship was not strong.\textsuperscript{13}
These studies differed from ours in that dyspnea was
measured retrospectively, and no attempt was made
to correlate results with a bronchodilator response. In
one study in which dyspnea was measured prospectively
during methacholine bronchoprovocation, 15
percent of asthmatic patients were unable to sense the
development of marked bronchoconstriction.\textsuperscript{14}

Our results differ from those of Mahler and Wells.\textsuperscript{2}
These authors concluded that clinical ratings of dyspnea
did correlate significantly with physiologic param-
eters of lung function. There are several important
differences between the two studies that may explain
this apparent dichotomy. First, unlike the former
study, our patients were not necessarily selected on
the basis of dyspnea. Thus, the correlation between
lung function and dyspnea in our study included data
from patients who were asymptomatic. Second, we
employed a Borg scale to measure resting dyspnea at
a single point in time, as well as the acute change
after bronchodilator. Mahler and Wells used a previ-
ously validated Baseline Dyspnea Index that is
designed to score breathlessness by relying on a patient's
history of recent functional impairment and activity-
related dyspnea.\textsuperscript{5} Finally, the data of Mahler and Wells
revealed that while the correlation between lung function and dyspnea for the smaller less obstructed
group of patients with asthma was very good ($r = 0.8$),
that for the larger more obstructed group with COPD
was only fair ($r = <0.4$).\textsuperscript{5} Our subjects as a group were
more severely obstructed than were the patients with
COPD of Mahler and Wells. The results of both
studies therefore may not be inconsistent and suggest
poor correlation between lung function and dyspnea
at least in more severely obstructed patients.

In this study we also found poor correlation between
change in pulmonary function as measured by spirom-
etry and change in dyspnea scores after bronchodila-
tor. Relatively few studies have used measures of
dyspnea to assess bronchodilator efficacy. While
improvement in exercise performance, dyspnea, and
pulmonary function have been demonstrated after both
albuterol and theophylline,\textsuperscript{15} the majority of studies have shown poor correlation between subjec-
tive and objective parameters.\textsuperscript{1,16-18} In many studies
the degree of bronchodilation has been small and one
study even suggested significant relief of dyspnea in
the absence of any bronchodilator effect of oral theo-
phylline.\textsuperscript{1} The poor correlation has prompted some
authors to suggest that drugs such as theophylline
may relieve dyspnea by mechanisms other than bron-
chodilation.\textsuperscript{19,20}

Mention must be made about our choice of indices
to measure airway obstruction and dyspnea. The
former was evaluated using FEV\textsubscript{1}, FVC, and FEF\textsubscript{25-75}.
In this report we have focused on the FEV\textsubscript{1} result,
although the data for the other measures were similar.
It can be argued that the results might have been
different had other tests of lung function been selected
to evaluate airway obstruction. Simple spirometric
values were chosen to assess the degree of obstruction
and reversibility because they are most frequently
used clinically. Berger and Smith\textsuperscript{21} showed that FEV\textsubscript{1}
was the best test to assess reversibility in patients with
chronic airway obstruction. Analyzing static lung vol-
umes, Raw, SGaw, or spirometric parameters other than FEV\textsubscript{1}
yielded little additional information.

Our choice of a dyspnea index was more difficult. A
number of dyspnea indices are now available.\textsuperscript{5} Those
in popular use have been validated and the correlation
between those commonly employed is very good.\textsuperscript{1,5}
However, these scales are based on history and
therefore are not ideally suited for measurement of
dyspnea at one specific point in time or to assess
change after bronchodilator therapy. The Borg scale
has been widely used to measure sensory perception.\textsuperscript{7}
It requires that the sensation to be rated be carefully
defined by the investigator. After this is done, baseline
scores may be obtained and ratings reflecting change
with acute intervention obtained. The Borg scale used
during exercise reproducibly reflects the effort of
breathing and correlates with physiologic param-
eters.\textsuperscript{28} Recently, a BDI was used to carefully measure
improvement in symptoms in patients with asthma
and COPD who were receiving bronchodilator admin-
istration during acute exacerbations.\textsuperscript{3} These data sug-

gest that a BDI is an acceptable technique for
measuring dyspnea as well as for recording change
after bronchodilator.

Traditionally, clinicians are accustomed to thinking
of patients as "responders" or "nonresponders" based
on the pulmonary function outcome after inhaled
bronchodilator administration in the laboratory.\textsuperscript{30} Our
study suggests that a similar arbitrary classification
can be imposed with respect to dyspnea. When these
end points are taken together, four categories instead
of the customary two are available to define the
response to inhaled albuterol (Table 2). Conventional
testing, by equating pulmonary function improvement
with relief of dyspnea or assuming that absence of
such response means lack of efficacy, fails to include
patients who respond in one or the other parameter
only. Twenty-eight of 65 initially dyspneic patients in
our study had either a dyspnea or bronchodilator
response, but not both.

The explanation for the relief of dyspnea in 17
patients without a concomitant change in FEV₁ must be speculative. As stated above, some have postulated independent cardiovascular or respiratory muscle beneficial effects of bronchodilators.19,20 While these effects are possible with systemically absorbed medications, this seems less likely after aerosolized bronchodilator. The placebo effect of bronchodilator medication is well known.17 This may well be more important after the administration of inhaled as compared with oral agents given the ritualistic technique normally used with the former. A weakness of the current study is failure to have included a placebo arm, and this will be addressed in follow-up studies. It is also impossible to determine to what extent dyspnea scores may have declined simply due to repeated measurement or consequent to learning. Further studies on these issues are necessary before dyspnea scoring can be recommended for clinical assessment in the laboratory.

It can be argued that in some individuals the subjective assessment of response to bronchodilator may be at least as valuable as objective data and therefore should not be dismissed. Shim and Williams8 suggested that during acute exacerbations of asthma, patients' subjective assessments were valuable in assessing their clinical status. Recently, Vestbo et al25 showed that the use of a dyspnea questionnaire yielded important additional information to that provided by the FEV₁, and was a good predictor of mortality. By showing poor correlation between subjective and objective data, the present study also suggests that measurement of dyspnea may yield information complementary to that obtained by spirometry. When used together these measures allow for a more detailed analysis of the response to bronchodilator in patients with OLD.

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REFERENCES

8 Mahler DA, Harver A. Minimizing the effects of dyspnea in COPD patients. J Respir Dis 1987; 8:23-34
12 Altose MD. Assessment and management of breathlessness. Chest 1985; 2:775-83
14 Rubinfeld AR, Pain MC. Perception of asthma. Lancet 1976; 1:982-84

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