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Validity of peak expiratory flow measurement in assessing reversibility of airflow obstruction

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Abstract

Background **Assessing the reversibility of airflow obstruction by peak expiratory (PEF) measurements would be practicable in general practice, but its usefulness has not been investigated.**

Methods **PEF measurements were performed (miniWright peak flow meter) in 73 general practice patients (aged 40 to 84) with a history of asthma or chronic obstructive lung disease before and after 400 μg inhaled salbutamol. The change in PEF was compared with the change in forced expiratory volume in one second (FEV_1). Reversible airflow obstruction was analysed in two ways according to previous criteria. When defined as a 9% or greater increase in FEV_1 expressed as a percentage of predicted values reversibility was observed in 42% of patients. Relative operating characteristic analysis showed that an absolute improvement in PEF of 60 l/min or more gave optimal discrimination between patients with reversible and irreversible airflow obstruction (the sensitivity and specificity of an increase of 60 l/min in detecting a 9% or more increase in FEV_1 as a percentage of predicted values were 68% and 93% respectively, with a positive predictive value of 87%). When defined as an increase of 190 ml or more in FEV_1, reversible airflow obstruction was observed in 53% of patients. Again an absolute improvement in PEF of 60 l/min or more gave optimal discrimination between patients with reversible and irreversible airflow obstruction (sensitivity 56%, specificity 94%, and positive predictive value 92%).**

Conclusion **Absolute changes in PEF can be used as a simple technique to diagnose reversible airflow obstruction in patients from general practice.**

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There is increasing evidence that reversibility of airflow obstruction occurs in patients with chronic obstructive lung disease as well as in those with asthma.[1–3] Several studies have shown that some patients with chronic obstructive lung disease show a substantial reversible component in their airflow obstruction.[4,5] Assessment of the presence and degree of reversibility of airflow obstruction is clinically important, particularly in elderly patients with asthma or chronic obstructive lung disease.[6]

Most patients with asthma or chronic obstructive lung disease are looked after by a general practitioner. In this setting a simple, reliable, and cheap method is needed to assess the severity of obstruction and its degree of reversibility. The measurement of peak expiratory flow (PEF) potentially meets these criteria. PEF within and between subjects correlates moderately well with the forced expiratory volume in one second (FEV_1) obtained by spirometry.[7] Hence assessing reversibility with a peak flow meter could be useful in the screening and follow up of patients with asthma or chronic obstructive lung disease. Although the use of the peak flow meter is widely advocated,[8,9] we are not aware of data on the validity of peak flow measurements in assessing reversibility of airflow obstruction in patients with asthma or chronic obstructive lung disease. We compared PEF and FEV_1 in assessing reversibility of airflow obstruction in middle aged and elderly patients with asthma or chronic obstructive lung disease and developed a practical criterion for assessing the presence of reversibility in general practice.

Patients and methods

Patients were recruited from three general practices in a health care centre responsible for 10 000 people near to Leiden University Hospital. The selection of patients was based on the requirement to obtain a representative population of patients from general practice with a broad range of airflow obstruction and reversibility. Patients were asked to participate in the study if they were 40 or more, known to the general practitioner as having a history of asthma or chronic obstructive lung disease (regardless of presenting symptoms), and had been prescribed treatment for lung disease (bronchodilators, cromoglycate, or steroids) in the 12 months preceding the study.[10] They were asked to visit the surgery to complete a questionnaire on medical history, based on the questionnaire of the British Medical Research Council and the European Community for Coal and Steel.[11] Inhaled treatment for lung disease was withheld for eight hours before the visit and theophyllines were withheld for 48 hours. FEV_1 and the inspiratory vital capacity (IVC) were measured with a calibrated rolling seal spirometer (Mijnhardt Volugraph 2000) and peak expiratory flow (PEF) by a mini-Wright peak flow meter, according to recommendations.[12] For all lung function measurements the largest of three satisfactory

Table 1 Patient characteristics (n = 73). Values are numbers of patients or means (SD) with ranges

Age (years)	61·9 (12·8)	40·0–84·0
Men	36	
Smoking state:		
Current smoker	24	
Ex-smoker	27	
Pulmonary treatment	49	
Corticosteroids		
Inhaled	20	
Oral	4	
Treated by lung specialist	15	
FEV_1:		
Litres	1·88 (0·89)	0·58–4·45
% Predicted values	70·7 (26·7)	20·4–118·0
FEV_1/IVC (% pred)	78·1 (22·5)	26·5–125·1
Increase in FEV_1 after bronchodilator:		
Litres	0·29 (0·30)	−0·03–1·38
% predicted values	10·6 (10·1)	−1·1–42·9
% above baseline values	20·3 (28·6)	−1·0–166·7
PEF (l/min):		
Baseline	344 (130)	100–630
Increase after bronchodilator	41 (42)	−40–160

FEV_1 = forced expiratory volume in one second; IVC = inspiratory vital capacity; PEF = peak expiratory flow.

attempts was recorded. Predicted values were calculated from reference values of the European Community for Coal and Steel.[12] Airflow obstruction was defined as an FEV_1 or FEV_1 to IVC ratio or both, below the 90% confidence interval of predicted values before bronchodilator.[12] Reversibility was assessed 15 minutes after inhalation of salbutamol 400 μg from a metered dose inhaler connected to a reservoir attachment (Nebuhaler).[13] Two measures of reversibility of airflow obstruction were used: (*a*) an increase after bronchodilator of 9% or more in FEV_1 expressed as a percentage of predicted values[14] and (*b*) an absolute increase of 190 ml or more in FEV_1.[15] PEF reversibility was expressed as the absolute change in l/min after bronchodilator. Sensitivity and specificity of PEF reversibility was analysed at different cut off points (relative operating characteristic analysis) for both measures of reversibility.[16]

ANALYSIS

Participants were compared with non-participants with respect to age, sex, prescribed treatment for lung disease, and the number of patients referred to a lung specialist by means of χ^2 and Student's *t* tests. Spearman rank correlations were calculated between reversibility, FEV_1 before bronchodilator, and age. All significance levels are two tailed.

Results

Of the 123 patients who met the inclusion criteria, seven were excluded because of a concomitant disorder and six because the general practitioner considered it too burdensome for them to participate; one person died before the start of the study. Of the remaining 109 patients, 73 were willing and able to visit the surgery (table 1). Patients participating in the study were older than those who did not ($t = 3·38$; df = 107; $p < 0·01$) and more had been prescribed treatment for lung disease ($\chi^2 = 4·25$; df = 1; $p < 0·05$). The sex and number of patients referred to a lung specialist did not differ significantly. Airflow obstruction was present in 46 of the 73 patients (an FEV_1 or FEV_1 to IVC ratio, or both, below the 90% confidence interval of predicted values[12]).

REVERSIBILITY

The distribution of the degree of reversibility for each variable is shown in figure 1. The mean (SD) increase in FEV_1 as a percentage of predicted values was 10·6% (10·1%) (table 1). Twenty four of the 46 patients with airflow obstruction (52%) showed a reversibility of 9% or more in predicted FEV_1. Reversibility, whether expressed as a percentage of predicted values or as an absolute increase in FEV_1, correlated negatively with age ($r = -0·36$, $p = 0·002$; $r = -0·52$, $p = 0·000$, respectively) but did not correlate significantly with FEV_1 (ml) before bronchodilator ($r = -0·13$, $p = 0·28$; $r = 0·02$, $p = 0·87$, respectively). Ten of the 34 patients over 65 showed a reversibility of 9% or more in FEV_1 expressed as a percentage of predicted values and 10 showed a reversibility of 190 ml or more in FEV_1.

The mean (SD) increase in PEF as a percentage of predicted values was 10·2% (11·1%). The correlation between the change in PEF and change in FEV_1 was 0·67 ($p < 0·001$).

With an increase in FEV_1 of 9% of predicted values as the measure of reversibility a plot was constructed of sensitivity and specificity against

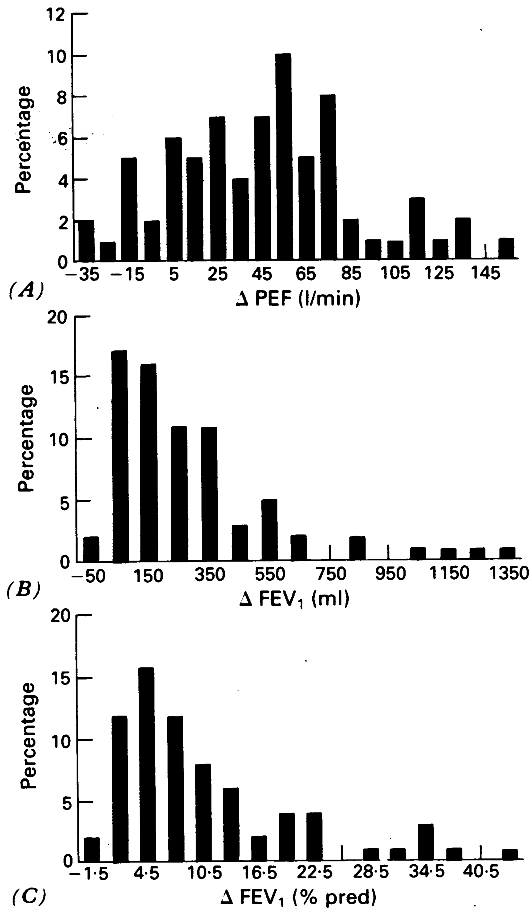
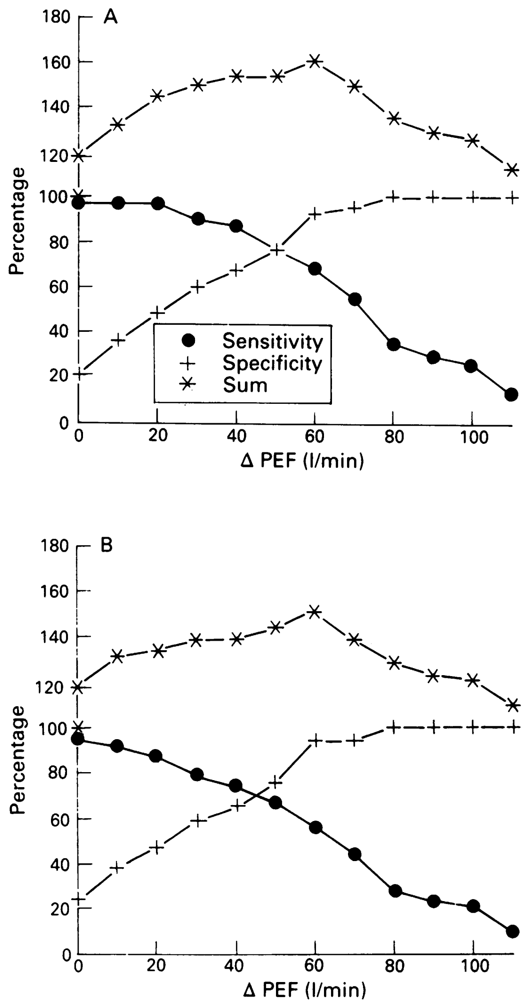


Figure 1 Relative distribution of bronchodilator response expressed as (A) absolute change in peak expiratory flow (PEF), (B) absolute change in FEV_1, and (C) change in FEV_1 as a percentage of predicted values.

Figure 2 Sensitivity and specificity of absolute improvement in peak expiratory flow (PEF). Measures of reversibility are (A) increase in FEV_1 $\geq 9\%$ of predicted values and (B) increase in FEV_1 ≥ 190 ml.



absolute PEF increase (figure 2). The sum of sensitivity and specificity was at its highest at a cut off point of an increase in PEF of 60 l/min (sensitivity 68%, specificity 93%; table 2). The same cut off point was found with an absolute improvement in FEV_1 of 190 ml as the measure of reversibility (sensitivity 56%, specificity 94%; figure 2). A lower cut off point results in higher sensitivities but lower specificities. For example, in figure 2(A) a cut off point of 40 l/min results in a sensitivity of 87% and a specificity of 67% (positive predictive value 66%, negative predictive value 87%).

Table 2 Sensitivity, specificity, and predictive values of absolute improvement in peak expiratory flow (PEF) after 400 μg salbutamol

	Improvement in FEV_1					
	% predicted values			*Absolute (ml)*		
Improvement in PEF (l/min)	≥ 9	< 9	*Total*	≥ 190	< 190	*Total*
≥ 60	21	3	24	22	2	24
< 60	10	39	49	17	32	49
Total	31	42	73	39	34	73
	Sensitivity		67·7%	Sensitivity		56·4%
	Specificity		92·9%	Specificity		94·1%
	Positive predictive value		87·5%	Positive predictive value		91·7%
	Negative predictive value		79·6%	Negative predictive value		65·3%

Discussion

In this study in elderly patients in general practice with a history of asthma or chronic obstructive lung disease the prevalence of reversible airflow obstruction was 42·5–53·4%, depending on whether the criterion of Dales *et al* (9% or more increase in FEV_1 as a percentage of predicted values)[14] or Tweeddale *et al* (increase in FEV_1 of 190 ml or more)[15] was used. After 400 μg inhaled salbutamol the predictive value of an increase in PEF of 60 l/min or more was respectively 87·5% and 91·7% in detecting an improvement in FEV_1 of 9% or more of predicted values or an increase of 190 ml or more. These results show the importance and feasibility of assessing the reversibility of airflow obstruction in general practice with a simple technique.

The effect of possible selection bias or methodological errors has been considered. Firstly, as we studied a general practice population selected on the basis of a history of asthma or chronic obstructive lung disease, our results will hold for screening only these types of patients. This population is an important one, however, and will include the majority of patients with asthma or chronic obstructive lung disease as they are treated only by general practitioners.[17] The group as a whole is probably representative of a typical heterogeneous population of patients with asthma or chronic obstructive lung disease treated in general practice. This approach makes our population to some extent comparable with those of Sourk *et al*, who studied bronchodilator response in a heterogeneous group of patients referred to a pulmonary function laboratory.[18]

Secondly, no attempt was made to discriminate between patients with asthma or chronic obstructive lung disease. The diagnostic label may be of minor importance, the response to treatment being the guiding principle, at least in general practice.[19,20]

Thirdly, our findings obviously depend on the measure of reversibility that we used. Various criteria for clinically relevant reversibility have been proposed recently (table 3). Tweeddale *et al* found that the absolute increase in FEV_1 correlated less well with baseline FEV_1 than did the percentage increase in FEV_1.[15] Dales *et al* found that the increase in FEV_1 when expressed as a percentage of predicted values showed little relation to baseline FEV_1 and was remarkably stable with sex, age, and height.[14] This finding is supported by the work of Eliasson *et al*[21] and more recently by that of Weir and Burge.[22] These findings strongly suggest that increase in FEV_1 expressed as a percentage of predictive values or as an absolute increase in FEV_1 are better ways of expressing reversibility of airflow obstruction than increase in FEV_1 expressed as a percentage of baseline FEV_1. In our analysis the results were highly comparable with either measure of reversibility in FEV_1—9% of predicted values or 190 ml.

Fourthly, the optimal cut off point for PEF reversibility was derived from the point at which the sum of sensitivity and specificity was

Table 3 Some recently developed criteria for reversibility of airflow obstruction

Reference	*Population*	*Agent*	*Analysis*	*Criterion (FEV_1)*
Sourk *et al* 1983[18]	40 patients referred to a pulmonary function laboratory (mean baseline FEV_1 60% of predicted values)	Placebo	Upper limit of 95% confidence interval	12·3% increase above prebronchodilator values or 178 ml
Tweeddale *et al* 1984[15]	54 healthy subjects and 13 patients with restrictive ventilatory defects	Natural variability	One tailed upper limit of 95% confidence interval	190 ml
Dales *et al* 1988[14]	2609 subjects without symptoms (FEV_1 > 80% predicted values)	Terbutaline 500 μg	95th Centile	9% predicted values (or 9% increase above prebronchodilator values or 291 ml)

at its highest, thus giving equal weight to both variables.[16] From a clinical point of view a high sensitivity might be more important than a high specificity. A lower cut off point could therefore be chosen based on the relative operating characteristic curves in figure 2, although this will result in a lower specificity and some loss of positive predictive value.

Finally, we do not have data on the repeatability of a PEF response to a bronchodilator. Data on the repeatability of bronchodilator responses would be hard to interpret because of the unknown relative contributions of random errors and the expected real biological variation in this population. The repeatability of the PEF itself is known to be not much worse than the repeatability of FEV_1.[23] As the repeatability of the criteria of Dales *et al* and Tweeddale *et al* are not known either, this subject deserves future attention.

The moderate correlation between improvement in PEF and FEV_1 is not unexpected. Although these two indices of pulmonary function are determined by somewhat different physiological mechanisms,[24] the relation between single measurements of PEF and FEV_1 is good.[7] Our results suggest that the bronchodilating effect of a β adrenergic agent can be documented by either variable. There are some limitations, however, in using PEF to detect reversible airflow obstruction, as defined by our "gold standard" improvement in FEV_1. The criterion of a 60 l/min or more increase in PEF was highly specific but not so sensitive. This means that a smaller increase in PEF does not exclude reversible airflow obstruction—for example, using a criterion of an increase in PEF of 40 l/min or more results in a sensitivity of 87% in detecting a reversibility of FEV_1 of 9% or more of predicted values and 74% in detecting a reversibility of FEV_1 of 190 ml or more. Failure of the FEV_1 to respond to a bronchodilator on a single occasion does not imply that the patient has irreversible airflow obstruction, as emphasised previously.[25] Some patients who do not show bronchodilatation as judged by a peakflow measurement may have partially reversible airflow obstruction which would have been detected by the FEV_1 or at a follow up visit after appropriate treatment by either PEF or FEV_1.

Our findings have clinical implications for general practice. Previous criteria for reversibility of airflow obstruction have mainly concerned the FEV_1. We have shown that reversibility of airflow obstruction in patients with asthma or chronic obstructive lung disease can be assessed by means of simple PEF measurements and give comparable results to those obtained by FEV_1. The criterion of an absolute increase in PEF of 60 l/min avoids having to make any calculations and seems to be an excellent way of predicting reversibility.

As the prevalence of reversibility of airflow obstruction in our population was between 40% and 50%, we recommend bronchodilator testing with a peak flow meter in general practice. Potentially reversible airway obstruction is often overlooked or misdiagnosed in elderly patients,[6] and we have found asthma to be undertreated in general practice.[26] Patients with asthma or chronic obstructive lung disease in general practice may benefit from a trial with bronchodilators.[27] The peak flow meter is a useful diagnostic tool in diagnosing reversibility of airflow obstruction with a high predictive value in patients in general practice who are 40 or more and have a history of asthma or chronic obstructive lung disease. This could help to improve the quality of care given by general practitioners to patients with asthma or chronic obstructive lung disease.

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