The Place of Forced Expiratory Volume in Relation to Other Lung Function Tests*

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The purpose of this study was to relate the forced expiratory volume (FEV1) to other lung function tests and to assess the factor of "reversibility." Six hundred thirty-five patients with "chronic nonspecific lung disease" were divided into those who showed an increase in the FEV1 after a bronchodilator aerosol (469) and those who showed no response (166). There was a linear relationship between the FEV1 and the steady-state diffusing capacity (gas transfer) which was most obvious in the non-responsive group and did not apply to the single breath technique of measuring gas transfer. There was a tendency for the PVR2 to rise with a failing FEV1, and, again, this was most marked in the non-responsive group, the PVR1 rising sharply for a FEV1 below one liter.

The findings suggest, especially when the FEV1 does not increase with the inhalation of a bronchodilator, that information about the steady-state Dco measurement may be deducted and an irreversible FEV1 below one liter usually indicates pulmonary insufficiency.

INTRODUCTION

Chronic airway obstruction occurs in a wide range of lung diseases which are grouped together under the heading of "chronic obstructive lung disease" or, in British terminology, "chronic nonspecific lung disease." The measurement of the degree of obstruction is the most frequent investigation that is carried out in pulmonary laboratories and, without using elaborate techniques, it is the most important. A moderate amount of airway obstruction will cause uneven ventilation in relation to blood flow and, in the later stages, will alter the blood gases and may lead eventually to right heart failure.

The object of this paper is to relate the forced expiratory volume used as a measurement of obstruction, to other lung function tests and to assess the importance of the factor of "reversibility."

Six hundred thirty-five patients who were referred for pulmonary assessment and who had a clinical diagnosis of chronic non-specific lung disease were used in the present investigation.

METHODS

The subjects were all ambulatory or semiambulatory patients; no bedridden patients were included. Chronic non-specific lung disease was diagnosed according to the definition proposed at the Ciba Symposium that these subjects with one or more of the following: chronic cough with expectoration, and paroxysmal or persistent excessive breathlessness, which are not solely attributable to: (a) localized lung disease of any kind; (b) generalized specific infective lung disease; (c) pneumoconiosis; (d) collagen diseases; (e) cardiovascular-renal diseases; (f) diseases of the chest wall; (g) psychoneurosis.

Each patient had a forced expiratory volume in one second (FEV1) measured in the semi-recumbent position, using a 9 liter spirometer filled with oxygen. The best of three attempts was taken as the result, the operator being satisfied that it represented a maximum effort. The measurement was repeated about seven minutes after a solution of 1 per cent isoproterenol sulfate had been inhaled through a nebulizer for a period of three minutes.

The pulmonary diffusing capacity was measured by the carbon monoxide, steady-state, end-tidal air sampling techniques, using a Cruth-Parnes infrared carbon monoxide analyzer. A smaller number of subjects had the Dco measured by the single breath method. Duplicate readings were made in every instance.

The mixed venous carbon dioxide tension (PvCO2) was estimated by the rebreathing technique of Campbell and Howell, using a Severinghaus electrode system in conjunction with a Vibron electrometer to measure CO2.

RESULTS

The first problem encountered was to decide what was a reversible or partly reversible response to the bronchodilator. There appeared to be some discrepancy in the literature as to the amount of improvement which was significant. It was therefore decided to divide the patients into those who showed some response, however slight (469), and those who showed no change at all (166). This also gave a more significant pattern to the results. Figure 1 shows the relationship between the PVR2 and FEV1 in subjects showing a response to isoproterenol.

It confirms the findings of Burrows et al. that there is a tendency for the PVR2 to rise in some patients with a decrease in FEV1 below one liter.

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also that it is less common to have carbon dioxide retention when the FEV₁ exceeds one liter.

Figure 2 shows the same relationship, but for the group which did not show any response to isoproterenol. In this group, the P\textsubscript{a\textsubscript{CO₂}} was elevated in the majority of patients with an FEV₁ of less than one liter. Of 41 such patients, only three had a P\textsubscript{v\textsubscript{CO₂}} below 46 mm Hg (P\textsubscript{v\textsubscript{CO₂}} is 6 mm Hg greater than P\textsubscript{A\textsubscript{CO₂}}). For a FEV₁ greater than one liter, the P\textsubscript{v\textsubscript{CO₂}} remains normal and the line is horizontal; below one liter there is a sharp rise in P\textsubscript{CO₂} values. In other words, below one liter, especially in complete irreversible obstructive disease, there is an inverse relationship between the FEV₁ and the P\textsubscript{a\textsubscript{CO₂}}.

The graph of the FEV₁ and the steady-state gas transfer measurement demonstrates a linear relationship with considerable scatter (Fig 3). This, again, is most striking in the group which showed no change following the inhalation of isoproterenol (Fig 4). In contrast to the steady state D\textsubscript{CO}, the single breath D\textsubscript{CO} values do not appear to be related in any way to the FEV₁, either in the reversible or the irreversible group (Fig 5).

DISCUSSION

At present, the cause of airway obstruction is not known.\textsuperscript{7} A significant amount of obstruction causes uneven distribution of inspired gas which may lead to a raised P\textsubscript{v\textsubscript{CO₂}} when the FEV₁ is below one liter. This is especially evident when the subject shows no response to a bronchodilator. The fact that there is no response suggests either a resistance to the drug or anatomic alteration in the bronchi.\textsuperscript{8} While the latter is more probable, it would not be possible to distinguish these two causes in the present series. It would appear that when the FEV₁ is less than one liter and shows no improvement following a bronchodilator, the P\textsubscript{v\textsubscript{CO₂}} will almost always be elevated. Furthermore, in these patients the steady-state diffusing capacity shows a good correlation with the FEV₁. Thus an FEV₁ below one liter suggests a raised P\textsubscript{v\textsubscript{CO₂}} and a decreased steady state D\textsubscript{CO}, both related to it in a linear manner.

When the ventilation is restricted as when the FEV₁ is below one liter it might be expected that the carbon dioxide levels would be raised. However, the reason for the relationship between the FEV₁ and the diffusing capacity (steady-state) is not quite so obvious. In the single breath technique,

![Figure 1](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21461/)

**Figure 1.** Relationship of FEV₁ to P\textsubscript{CO₂} in subjects who showed a response to the bronchodilator.

![Figure 2](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21461/)

**Figure 2.** Relationship of FEV₁ to P\textsubscript{v\textsubscript{CO₂}} in subjects who showed no response to the bronchodilator.

![Figure 3](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21461/)

**Figure 3.** Relationship of the FEV₁ and D\textsubscript{CO} (steady-state) in subjects who showed a response to the bronchodilator.

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which does not show this pattern, the CO measurement is relative to an inert insoluble gas and the fact that the breath is held for some time allows the mixture to reach poorly ventilated areas. The steady-state technique, on the other hand, theoretically has a higher dependency on the ventilation/perfusion ratios, particularly when sampling end-tidal gas. However, it has been shown in this laboratory and in others that the gas transfer factor by this method does not increase after the inhalation of isoproterenol. In fact, we have found in many cases there is a tendency for it to decrease. This might suggest that there is a higher dependency on the perfusion rate rather than the ventilation. Whether this is true or not, there is a greater reduction of the steady-state Dm in emphysema than the single breath method and it is a sensitive index of the disease.

It is concluded that an irreversible FEV₁ of less than one liter is an important indication of pulmonary insufficiency, being usually associated with a raised PV̇O₂ and a low steady-state gas transfer measurement.

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