A comparison of pulmonary function in bronchial asthma and chronic obstructive bronchitis

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The dynamic and static lung volumes, arterial blood-gas tensions, and single-breath carbon-monoxide transfer factor have been compared in 72 asthmatic and 45 bronchitic patients with airways obstruction of comparable severity to determine which measurements might be used to discriminate between the two diseases. The forced vital capacity, total lung capacity, arterial carbon-dioxide tension, and transfer factor were useful in this respect. Thus, in a patient with airways obstruction the finding of a low % predicted FVC (<70) and a low % predicted DLco (<50) with a relatively normal % predicted TLC and a raised P_{aCO_2} is strongly suggestive of chronic obstructive bronchitis, whereas the finding of a relatively normal % predicted FVC and a high % predicted TLC (>115) with a nearly normal DLco and a normal or low P_{aCO_2} is most compatible with a diagnosis of bronchial asthma.

Generalized obstruction of the small bronchial airways is a characteristic feature of both bronchial asthma and chronic obstructive bronchitis. This leads to important changes in dynamic and static lung volumes, blood-gas tensions, and transfer factor and we have reported how these measurements are altered in both asthmatic and bronchitic subjects (Palmer and Diament, 1969a, b). However, because the functional changes in the two diseases are similar, a sharp separation based on physiological abnormalities is not always possible, and to determine whether any particular measurement or group of measurements could be used to differentiate between them we have here compared the changes in pulmonary function in the two diseases. Because our asthmatic subjects were younger and there were more females than in the bronchitic group, it has been necessary to standardize the measurements by first determining the predicted normal value for each patient (based on age, sex, height, and weight) and then expressing the absolute measurements as a percentage of the predicted normal values.

PATIENTS AND METHODS

There were 117 subjects—72 asthmatic and 45 obstructive bronchitic. The mean ages, heights, and weights ($\pm$ SD) are shown in Table I. Forty asthmatics (55.5%) and nine bronchitics (20.0%) were women. The asthmatics had a history of attacks of acute airways obstruction with little or minimal disability between attacks. They all had at some time sputum

or blood eosinophilia and the majority had positive skin tests to various allergens. The bronchitics were for the most part heavy cigarette smokers who had a long history of productive cough and attacks of breathlessness, usually associated with purulent sputum—most often after upper respiratory tract infections. None had blood or sputum eosinophilia.

The methods used for obtaining the dynamic and static lung volumes, blood-gas tensions, and transfer factor were as described previously (Palmer and Diament, 1969a, b). For purposes of comparison the mean values are expressed as percentages of the predicted normal values using the data of the Committee on Rating of Mental and Physical Impairment (1965) for dynamic lung volumes, of Needham, Rogan, and McDonald (1954) for static lung volumes, of Ogilvie, Forster, Blakemore, and Morton (1957) for the single-breath carbon monoxide transfer factor, and our own data for arterial blood-gas tensions (Diament and Palmer, 1969). The prediction formulae used for the dynamic lung volumes are dependent on age, sex, and height, those for the static lung volumes on age, sex, height, and weight, the arterial blood-gas tensions on age and sex, and the transfer factor on height alone. The only significant differences between asthmatics and bronchitics were mean age and sex; there was no significant difference between mean weight and height.

RESULTS

Table I shows the mean values ($\pm$ SD) for dynamic lung volumes [forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), and FEV_1 expressed as a percentage of FVC ($FEV_1\%$)], static lung volumes [total lung

capacity (TLC), functional residual capacity (FRC), residual volume (RV), and RV/TLC%, arterial oxygen tension (Pao₂) and transfer factor (Dlco), expressed as a percentage of the individual predicted normal values. The mean arterial carbon dioxide tension (Paco₂) is given in absolute values since it does not vary with age, sex or height (Diamant and Palmer, 1969).

TABLE I

MEAN % PREDICTED DYNAMIC AND STATIC LUNG VOLUMES, ARTERIAL BLOOD-GAS TENSIONS (mm. Hg), AND TRANSFER FACTOR (ml./min./mm. Hg) ($\pm$ SD) IN 72 ASTHMATIC AND 45 CHRONIC OBSTRUCTIVE BRONCHITIC SUBJECTS

	Asthmatics	Bronchitics	P
Age (yr.)	30.6 ($\pm$ 19.4)	59.5 ($\pm$ 10.1)	< 0.001
Height (in.)	65.1 ($\pm$ 3.2)	66.0 ($\pm$ 2.6)	N.S.
Weight (lb.)	137.0 ($\pm$ 26.8)	129.0 ($\pm$ 24.9)	N.S.
% Predicted FEV ₁	54.5 ($\pm$ 17.6)	37.2 ($\pm$ 19.0)	< 0.001
" FVC	87.6 ($\pm$ 21.7)	64.0 ($\pm$ 24.5)	< 0.001
" FEV ₁ %	61.5 ($\pm$ 11.4)	57.4 ($\pm$ 15.0)	N.S.
" TLC	121.4 ($\pm$ 21.1)	107.5 ($\pm$ 20.9)	< 0.001
" FRC	172.1 ($\pm$ 45.9)	184.4 ($\pm$ 59.7)	N.S.
" RV	185.5 ($\pm$ 50.8)	200.0 ($\pm$ 76.6)	N.S.
" RV/TLC %	159.9 ($\pm$ 39.5)	167.3 ($\pm$ 36.9)	N.S.
" Dlco	78.2 ($\pm$ 21.5)	44.3 ($\pm$ 23.7)	< 0.001
" Pao ₂	84.6 ($\pm$ 11.3)	79.4 ($\pm$ 14.6)	N.S.
Mean Paco ₂ (mm.Hg)	39.5 ($\pm$ 4.9)	50.1 ($\pm$ 13.1)	< 0.001

N.S. = not significant

Whilst there was no significant difference in FEV₁% and therefore in the degree of airway obstruction between the asthmatics and bronchitics, both FVC and FEV₁ were significantly lower in the bronchitics. Of the static lung volumes, TLC was significantly higher in the asthmatics, but whilst FRC, RV, and RV/TLC% were all much increased from normal in both, there was no significant difference in the extent of

the increase between them. Both groups had hypoxaemia of comparable degree, but the Paco₂ was significantly higher in the bronchitics. The Dlco was slightly reduced in the asthmatics but to a significantly greater degree in the bronchitics.

The results of these tests, depending on the degree of airway obstruction, again expressed as % predicted normal values, are shown in Table II. There are three groups: mild airway obstruction, FEV₁% 55-69; moderate, FEV₁% 40-54; and severe, FEV₁% <40. There was a greater reduction in % predicted FVC and FEV₁ in bronchitics than in asthmatics for all grades of airway obstruction, this change reaching significant levels for FVC in the mild and severe groups but only in the severe group for FEV₁. The % predicted TLC was greater in the asthmatic than in the bronchitic in the mild and moderate groups, but the differences in the other static lung volumes were not significant. The Pao₂ showed a progressive fall with increasing airway obstruction in both diseases, but this was accompanied by a rising Paco₂ level in the bronchitic group, whereas the

TABLE III

EFFECT OF BRONCHODILATOR ON MEAN FEV₁ (LITRES A.T.P.S.) ($\pm$ SD)

	Asthmatics	Bronchitics
FEV ₁ pre-bronchodilator ..	1.56 ($\pm$ 0.61)	0.98 ($\pm$ 0.49)
FEV ₁ post-bronchodilator ..	1.88 ($\pm$ 0.70)	1.11 ($\pm$ 0.54)
Mean increase in FEV ₁ ..	0.32 ($\pm$ 0.25)	0.13 ($\pm$ 0.14)
Mean % increase in FEV ₁ ..	21.9 ($\pm$ 20.4)	14.6 ($\pm$ 13.3)

TABLE II

MEAN DYNAMIC AND STATIC LUNG VOLUMES, ARTERIAL BLOOD-GAS TENSIONS, AND TRANSFER FACTOR ($\pm$ SD) EXPRESSED AS % PREDICTED NORMAL VALUES IN 72 ASTHMATIC AND 45 BRONCHITIC PATIENTS WITH AIRWAY OBSTRUCTION OF INCREASING SEVERITY

	Mild FEV ₁ % 55-69		P	Moderate FEV ₁ % 40-54		P	Severe FEV ₁ % < 40		P
	Asthmatics	Bronchitics		Asthmatics	Bronchitics		Asthmatics	Bronchitics	
No.	29	9		34	21		9	15	
Age (yr.)	40.8 ($\pm$ 15.7)	63.8 ($\pm$ 8.9)	< 0.001	39.7 ($\pm$ 12.0)	61.1 ($\pm$ 10.2)	< 0.001	37.6 ($\pm$ 14.7)	54.4 ($\pm$ 9.8)	< 0.01
Height (in.)	65.3 ($\pm$ 2.8)	66.5 ($\pm$ 2.4)	N.S.	65.5 ($\pm$ 3.1)	66.1 ($\pm$ 2.9)	N.S.	64.9 ($\pm$ 3.5)	65.4 ($\pm$ 2.5)	N.S.
Weight (lb.)	136.9 ($\pm$ 20.2)	131.3 ($\pm$ 21.6)	N.S.	141.5 ($\pm$ 27.7)	131.5 ($\pm$ 25.4)	N.S.	131.3 ($\pm$ 15.6)	118.7 ($\pm$ 23.7)	N.S.
% predicted									
FEV ₁	67.0 ($\pm$ 16.1)	51.2 ($\pm$ 24.0)	N.S.	49.3 ($\pm$ 12.2)	41.7 ($\pm$ 14.9)	N.S.	34.2 ($\pm$ 9.1)	22.6 ($\pm$ 10.0)	< 0.01
FVC	94.6 ($\pm$ 20.8)	66.8 ($\pm$ 28.1)	< 0.01	82.8 ($\pm$ 22.5)	70.7 ($\pm$ 24.5)	N.S.	81.6 ($\pm$ 21.8)	52.8 ($\pm$ 19.3)	< 0.005
FEV ₁ %	72.4 ($\pm$ 5.2)	80.4 ($\pm$ 9.3)	< 0.02	57.3 ($\pm$ 5.2)	58.6 ($\pm$ 4.7)	N.S.	42.1 ($\pm$ 2.8)	41.8 ($\pm$ 5.3)	N.S.
TLC	117.1 ($\pm$ 25.6)	97.1 ($\pm$ 24.1)	< 0.05	123.7 ($\pm$ 18.1)	107.9 ($\pm$ 16.4)	< 0.005	126.2 ($\pm$ 14.0)	113.6 ($\pm$ 23.7)	N.S.
FRC	163.1 ($\pm$ 37.6)	151.7 ($\pm$ 58.8)	N.S.	173.8 ($\pm$ 49.8)	179.1 ($\pm$ 43.4)	N.S.	198.4 ($\pm$ 51.4)	206.0 ($\pm$ 84.6)	N.S.
RV	161.9 ($\pm$ 40.9)	152.8 ($\pm$ 49.2)	N.S.	192.3 ($\pm$ 48.4)	185.4 ($\pm$ 49.6)	N.S.	235.9 ($\pm$ 47.9)	252.2 ($\pm$ 96.4)	N.S.
RV/TLC	145.0 ($\pm$ 28.3)	147.5 ($\pm$ 15.3)	N.S.	163.5 ($\pm$ 42.7)	160.7 ($\pm$ 32.3)	N.S.	194.3 ($\pm$ 36.3)	190.6 ($\pm$ 42.6)	N.S.
Dlco	86.3 ($\pm$ 16.9)	38.5 ($\pm$ 26.6)	< 0.01	75.4 ($\pm$ 22.4)	48.6 ($\pm$ 25.2)	< 0.001	63.1 ($\pm$ 22.3)	41.9 ($\pm$ 21.2)	N.S.
Pao ₂	89.0 ($\pm$ 69.3)	86.3 ($\pm$ 11.5)	N.S.	82.6 ($\pm$ 9.7)	81.1 ($\pm$ 13.2)	N.S.	79.1 ($\pm$ 17.4)	73.5 ($\pm$ 16.4)	N.S.
Paco ₂ (mm.Hg)	37.8 ($\pm$ 3.6)	41.1 ($\pm$ 7.2)	N.S.	40.7 ($\pm$ 6.1)	47.2 ($\pm$ 8.7)	< 0.01	39.9 ($\pm$ 4.2)	60.5 ($\pm$ 15.7)	< 0.001

$Paco_2$ remained low or normal in the asthmatics. The $DLco$ fell in the asthmatics somewhat as airway obstruction increased, but in the bronchitics it remained at a fixed low level irrespective of the degree of airway obstruction.

Table III shows the changes in FEV_1 following the aerosol inhalation of a bronchodilator in the two groups. In both there was a significant rise in FEV_1 after the drug, the rise in the asthmatics being significantly greater than in the bronchitics both as an absolute and percentage increase.

DISCUSSION

A basic difficulty in comparing the changes in pulmonary function in asthmatic and bronchitic patients is that asthmatics are frequently young and female, whereas bronchitics are predominantly older men, and most pulmonary function measurements are dependent on the variables, age, sex, and height, and in some instances weight also. To overcome this difficulty we have expressed the measurements of the dynamic and static lung volumes, Pao_2 and $DLco$ as percentages of the individual predicted normal value for each patient.

Although the degree of airways obstruction did not differ between asthmatics and bronchitics, both % predicted FVC and FEV_1 were significantly lower in the bronchitics, this difference being greater for FVC (23.6, SE 0.92) than for FEV_1 (17.3, SE 0.81). The % predicted FVC, however, was still greater in severe asthma than it was in mild bronchitis, whereas the % predicted FEV_1 tended to fall to the same extent in both, depending on the extent of the airway obstruction. We think, therefore, that the % predicted FVC is a better measurement than % predicted FEV_1 to separate the two diseases. This is in keeping with our observations that FEV_1 reflects both obstructive and restrictive elements of ventilatory impairment whereas FVC is not a measure of airway obstruction but indicates solely a restrictive ventilatory defect secondary to lung hyperinflation which develops progressively as airway obstruction increases (Palmer and Diamant, 1968a, b). We have also suggested that $RV/TLC\%$ is the best index of such hyperinflation in both diseases (Palmer and Diamant, 1969a, b), but although the $RV/TLC\%$ was much increased in both the asthmatics and bronchitics, the extent of the increase did not differ between them. This means that for a comparable degree of hyperinflation, bronchitic patients will have a greater restrictive impairment than do asthmatics. This indicates an additional

factor leading to restrictive ventilatory impairment in bronchitis and may well reflect the presence of peribronchial fibrosis. This could also explain why the TLC was significantly larger in asthmatics than in bronchitics.

Whilst FVC, FEV_1 , and TLC were significantly different between asthmatics and bronchitics, the indices of hyperinflation (FRC, RV, $RV/TLC\%$) were not different and therefore have little or no value in distinguishing between the two diseases. $Paco_2$ was significantly higher in bronchitics than in asthmatics and rose in the bronchitics but not in the asthmatics as the airway obstruction increased. It is of interest that there was no significant difference in Pao_2 for the groups as a whole or for any of the sub-groups. This indicates that, whatever the physiological difference may be between asthma and bronchitis, it does not affect the degree of hypoxaemia.

For comparable airway obstruction $DLco$ is reported to be well preserved in patients with chronic obstructive bronchitis but to fall progressively when this disease is associated with emphysema (Fletcher, Hugh-Jones, McNicol, and Pride, 1963). Burrows, Niden, Barclay, and Kasik (1965) found low mean values for this test in subjects with irreversible airways obstruction and there was some relationship between the fall in $DLco$ and the severity of the airway obstruction. We found the mean $DLco$ to be less than 50% of predicted normal value in the bronchitics and it remained at this low level whatever the degree of airway obstruction. $DLco$ is generally described as being normal in asthma (Meisner and Hugh-Jones, 1968; Bedell and Ostigury, 1967). We found the mean % predicted $DLco$ was reduced somewhat in asthma and that it fell further as airway obstruction increased. The $DLco$, therefore, in our experience is quite different in asthma and obstructive bronchitis. It is fixed at a nearly constant low level in obstructive bronchitis, but although it is slightly reduced in mild asthma it continues to fall with increasing airway obstruction. We regard this as a useful test to differentiate the two diseases.

Airway obstruction was reduced by aerosol bronchodilators in both diseases. In asthmatics there was a mean rise in FEV_1 of over 20%, but in bronchitics the mean rise was only 15%, which is significantly less than that for the asthmatics (Table III).

We conclude from our findings that for equivalent degrees of airway obstruction there are significant differences between asthmatics and bronchitics in several of the pulmonary function

measurements, and we suggest that these measurements may be used as an aid in the clinical differentiation of the two diseases. It happens that one measurement each of the static lung and dynamic lung volumes and the blood-gas tensions together with the transfer factor turns out to be a useful discriminator in this respect. Thus, in a patient with airways obstruction, the finding of a low % predicted FVC (<70) and a low % predicted DLco (<50) with a relatively normal % predicted TLC and a raised PaCO_2 is strongly suggestive of chronic obstructive bronchitis, whereas the finding of a relatively normal % predicted FVC and a high % predicted TLC (>115) with a nearly normal DLco and a normal or low PaCO_2 is most compatible with a diagnosis of bronchial asthma.

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