require help at an early stage. It is recommended that area co-ordinating services for head injuries be set up, and some rehabilitation centres developed to deal especially with particular injuries.

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Pulmonary Function in Bronchial Asthma*

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Compared with the large number of pulmonary function studies that have been made in patients with air-flow obstruction from bronchitis or emphysema, there have been relatively few in patients with spasmodic bronchial asthma (Bates and Christie, 1964). Some clinicians hold that asthma, in contrast with bronchitis and emphysema, does not cause serious disturbance of the blood gases, though the reports of Herschfus *et al.* (1953), Williams and Zohman (1959), and several studies in the past 12 months do not support this view.

Clinically, asthma patients may be divided into two types—those ("extrinsic") who show definite sensitivity to external allergens and those ("intrinsic") who do not. The purpose of this report is to help to define the extent of the functional lesion as air-flow obstruction varies in asthma, to try to find out how it differs from the changes in function in bronchitis and emphysema, and to see whether there is any functional difference between the clinical types of extrinsic and intrinsic disease.

The present paper reports the changes which occurred in the total lung capacity, in the carbon monoxide transfer factor, and in the arterial blood gases as the air-flow obstruction varied, in nine patients with severe spasmodic bronchial asthma, five of whom were selected as having the extrinsic and four as having the intrinsic type of asthma. These changes are contrasted with those in a group of 15 patients with chronic bronchitis and radiological evidence of emphysema who had relatively fixed air-flow obstruction.

The results of the work show how various tests of lung function can be helpful clinically as a guide to the treatment of patients and suggest the importance of the frequent measurement or the continuous monitoring of the P_{CO_2} in severe attacks of asthma.

Selection of Patients

Asthma

We chose for study only patients who fulfilled certain criteria of being asthmatic, but showed no evidence of any complicating disease, especially infected bronchitis or emphysema. We followed two recent expert committees (Ciba Guest Symposium, 1959 ; American Thoracic Society, 1962) in defining asthma as variable air-flow obstruction. We used two criteria of variability. Any patient selected for study had to have had at least two attacks of wheezing breathlessness interspersed with symptom-free periods. The $F.E.V._1$ must have been shown to vary by at least 30% of the predicted value at different times in the previous six months. In all our patients variation of the $F.E.V._1$ was at least 0.97 litre (Table I) and the best values approached normal. We tried to get patients who showed an increase in eosinophils in their blood or sputum, especially when they were thought to be examples of extrinsic asthma.

TABLE I.—*Clinical Features of Patients*

Case No.	Age	Sex	F.E.V.$_1$ (l.) Maximum	F.E.V.$_1$ (l.) Minimum	F.E.V.$_1$ (l.) Predicted	Age at Onset (Years)	Eosinophils Blood (/ml.)	Eosinophils (Sputum %)	Cigarettes (/day)	Sputum (ml./day)	History of Allergy	Skin Tests
					Group 1							
1	31	F	2·15	0·48	3·05	0	1,600	20	–	–	+	House dust
2	30	F	2·65	1·40	2·93	0	400	6	20*	–	+	Cats. Feathers
3	34	F	2·65	1·40	2·07	7	N.R.	–	–	–	+	House dust. Feathers
4	40	F	1·84	0·75	2·08	3	720	–	–	–	+	Grass pollen
5	41	M	1·97	0·54	3·85	9	N.R.	–	–	–	+	House dust
					Group 2							
6	41	M	3·44	0·65	3·05	40	810	–	–	–	–	–
7	53	F	1·97	0·65	2·01	49	530	–	–	–	–	–
8	56	F	1·30	0·38	2·01	47	220	1	–	–	–	–
9	56	M	1·95	0·43	2·80	55	525	–	20*	<5	–	–

* = Nil for last year. N.R. = Not recorded.

We excluded any patient with an abnormal electrocardiogram or a diastolic blood pressure greater than 110 mm. Hg. We tried to exclude coexisting chronic bronchitis by rejecting subjects who had smoked more than 20 cigarettes a day and who, in clinical remission, produced more than 5 ml. of sputum a day or had clinically infected sputum (in fact only one of our subjects (Case 9, Table I) had any sputum at all during remission of asthma).

In addition, the chest radiographs of all prospective patients were examined for evidence of emphysema by two radiologists

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who worked independently. If emphysema was suspected in any zone of the lung field by either radiologist the patient was rejected, using for the radiological diagnosis attenuation of the peripheral vascular pattern but ignoring signs of general over-inflation of the lungs (Fraser and Bates, 1959 ; Laws and Heard, 1962).

Using the above criteria for selection of patients as having asthma, we classified them into two clinical groups: group 1 ("extrinsic"), whose symptoms started before the age of 15 years, who gave a history of other allergies (such as eczema in childhood, hay-fever, sensitivity to house dust, cats, feathers, pollens, etc.), and who had positive skin tests ; and group 2 ("intrinsic"), whose symptoms started after the age of 30 years and who had no history of allergy or any skin sensitivity. It was impossible to match the ages of the two groups, the mean age of group 1 being 35 years and that of group 2 52 years (Table I).

Chronic Bronchitis and Emphysema

We selected for comparison 15 patients with chronic expectoration, definite radiological evidence of emphysema, and relatively fixed and severe air-flow obstruction. This group was chosen from patients studied routinely in this laboratory over the last two years by exactly the same methods. Their ages ranged from 40 to 59 years, and their F.E.V.$_1$ from 0.54 to 1.12 l., but showed minimal variation from one time to another.

Methods

All tests, except the arterial blood gas measurements, were performed with the patients in the sitting position, and gas volumes were corrected to body temperature, pressure, and saturation.

Tests of Ventilation.—The forced expiratory volume in one second (F.E.V.$_1$) and the vital capacity (V.C.) were measured on a low-resistance spirometer with a drum speed of 1.97 cm./sec. The maximum values of three attempts were taken. Normal values for F.E.V.$_1$ were predicted from the regression formulae of Kory *et al.* (1961) for males and of Kory *et al.* (1968) for females.

Lung Volumes.—Two methods were used. (*a*) *Closed-circuit helium dilution.*—The functional residual capacity (F.R.C.) was measured in duplicate by the technique of Gilson and Hugh-Jones (1949). The end-point of equilibration was taken where the helium katharometer showed less than 0.1% change in one minute. The average time taken over equilibration was five to seven minutes. Duplicates had to agree within 10%, or a third measurement was carried out. A vital capacity manœuvre was performed when equilibration was complete, and total lung capacity (T.L.C.) and residual volume (R.V.) were measured. (*b*) *Whole body plethysmography.*—Thoracic gas volume was measured by the method of DuBois *et al.* (1956), except that we used a volume-displacement plethysmograph (Mead, 1960) to measure volume changes directly. With this method the lung volume is obtained by occluding the airway at the mouth at the end of a tidal expiration and measuring the changes in mouth pressure and box volume during panting efforts against the closed valve. The valve was then opened and the subject inspired to full inflation. The T.L.C. was obtained by adding this inspired volume to the volume measured when the valve was closed. The mean of three or four measurements was recorded. The results were compared with the predicted values of Goldman and Becklake (1959).

Gas Transfer.—Carbon monoxide transfer factor (T_{LCO}) was measured by the single-breath method of Ogilvie *et al.* (1957), except that breath-holding time was calculated in the manner suggested by Jones and Meade (1961). The mean of three measurements at full inflation was taken. For the calculation of T_{LCO} we have followed the original authors in assuming that alveolar volume (V_A) during breath-holding was the sum of the inspired volume of CO-He mixture and the R.V. measured a few minutes later by the multibreath closed-circuit helium-dilution method. We have also calculated the CO transfer per litre of lung volume (T_L/V_A) by dividing the value of T_{LCO} by the alveolar volume (expressed in litres at body temperature, pressure, and saturation). The results were compared with the predicted values of Hamer, Cotes, and Meade (see Cotes, 1965) for men and of Newman (1963) for women.

Analysis of Arterial Blood and Expired Gas.—The patients were studied while lying at rest with their backs raised 35° above the horizontal. After a polyethylene cannula had been introduced into the brachial artery the patient breathed room air through a mouthpiece and valve box. Respiratory rate and end tidal CO_2 tension were monitored by a respiratory mass spectrometer sampling gas at the mouthpiece. When the end tidal CO_2 tension was constant expired gas was collected for washing out a Douglas bag ; a second collection of expired gas was then made for three minutes and an arterial blood sample was taken in the last minute of this gas collection. Measurements of arterial carbon dioxide tension ($Paco_2$), oxygen tension (Pao_2), and *p*H were made immediately after sampling by means of Radiometer electrodes. Mixed expired gas samples were analysed for carbon dioxide and oxygen content in the Lloyd–Haldane apparatus (Lloyd, 1958), and the volume of the expired gas was measured in a Tissot spirometer. From these measurements physiological dead space (V_D) as a fraction of the tidal volume (V_T) was calculated by the use of the Bohr equation for CO_2, and alveolar oxygen tension (PAo_2) was calculated from the alveolar air equation. From the difference between alveolar and arterial oxygen tensions ($A\text{-}aDo_2$) the proportion of the total cardiac output which could be regarded as venous admixture was estimated from the charts of Riley and Cournand (1949). It was assumed that the arteriovenous oxygen saturation difference was 20% and that there was no difference between alveolar and end-capillary oxygen tensions.

In five patients at the end of the procedure 2.25 mg. of orciprenaline was inhaled from a pressurized aerosol. The change in F.E.V.$_1$ was measured 20 minutes later and the blood gas and expired air study was then repeated.

Results

In order to compare patients of different age, sex, and size we have, in graphs, used values expressed as a percentage of predicted normal, though we give the absolute values as well in the Tables. The use of predicted values for T.L.C. and T_{LCO} was justified by their close agreement with the results in 20 healthy subjects studied in this laboratory. In our normal series the mean value of T.L.C. was 97% of that predicted and the mean value of T_{LCO} was 98% of that predicted.

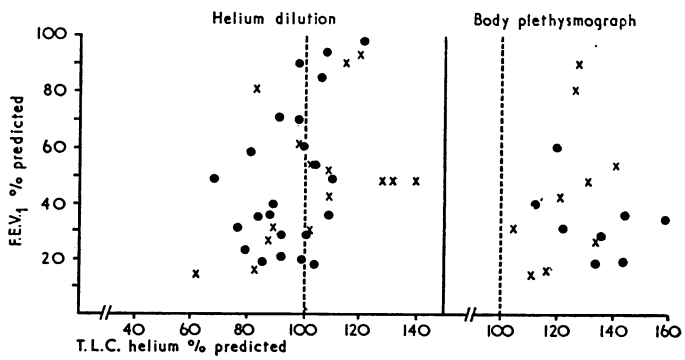

FIG. 1.—F.E.V.$_1$ (% predicted) plotted against T.L.C. (% predicted) measured by helium dilution and whole body plethysmography. In this Figure and in Figs. 2, 4, and 5 circles indicate patients with intrinsic asthma and crosses patients with extrinsic asthma.

Total Lung Capacity.—Table II gives the values for the F.R.C. and the T.L.C. with different degrees of air-flow obstruction, as measured by the F.E.V.$_1$, for the two groups of patients respectively. As expected, the residual volume tended to be increased when the airways obstruction, as indicated by a low F.E.V.$_1$, was most severe. When the results for the T.L.C. measurements are plotted graphically for the two different techniques of measurements (Fig. 1) it is seen that in both groups of patients T.L.C. appears to be underestimated by helium dilution when airways obstruction is severe, and that T.L.C. is shown to be increased in both mild and severe asthma by the whole body plethysmograph. Thus, in this small number of moderately severe asthmatic patients, pulmonary hyperinflation is present as measured by whole body plethysmography. With the helium-dilution technique the R.V./T.L.C. ratio was slightly raised in both groups of patients, but was markedly raised when measured with the plethysmograph (Table II).

TABLE II

Case No.	Date	F.E.V.$_1$ (l.)	F.E.V.$_1$ (% pred.)	Lung Volumes: Helium T.L.C. (l.)	Helium T.L.C. (% pred.)	Helium R.V./T.L.C. %	Plethysmograph T.L.C. (l.)	Plethysmograph T.L.C. (% pred.)	Plethysmograph R.V./T.L.C. %	CO Transfer T_{LCO} (ml./min./mm.Hg)	CO Transfer T_{LCO} (% pred.)	CO Transfer T_L/V_A	CO Transfer T_L/V_A (% pred.)
							Group 1						
1	24/9/65	1·9	62	5·1	98	21				22·4	95	4·5	97
	25/10/65	2·15	70							26·8	113	4·1	90
	3/3/66	2·49	81	4·3	83	35	6·5	127	58				
	24/3/66	0·48	16	4·3	83	49	6·0	116	72	18·6	78	4·4	95
	24/5/66	0·92	30	5·2	102	38				23·8	100	4·9	106
2	31/1/66	1·4	48	5·8	128	45	5·9	131	46				
	4/3/66	2·7	93	5·4	120	33							
	17/5/66	2·65	90	5·2	115	25	5·8	128	33	22·2	101	4·6	94
3	17/5/66	1·46	54	5·0	102	36	6·9	141	54	23·8	105	5·0	110
	7/6/66	1·41	52	5·3	109	34				26·2	115	5·3	116
	28/7/66	1·51	56							19·7	87	5·5	120
4	5/5/66	0·86	31	4·4	89	43	5·2	105	52	22·4	98	5·4	119
	7/6/66	0·75	27	4·3	88	51	6·6	134	67	17·5	77	4·3	94
5	26/4/66	1·67	43	7·2	109	51	8·0	121	66	32·2	111	4·5	102
	12/5/66	0·54	14	4·1	62	68	7·3	111	81	24·7	85	6·1	138
							Group 2						
6	29/6/66	0·75	21	5·5	92	41				28·5	112	5·1	117
	21/7/66	0·65	19	5·1	85	68	8·6	143	73				
	15/9/66	3·44	98	7·3	121	35				35·0	137	5·0	113
	22/11/66	1·73	49	6·6	110	33				35·4	139	5·3	121
7	26/2/65	1·97	94	5·3	108	40							
	1/4/65	1·24	59	4·0	81	49							
	27/5/65	2·0	95	4·8	98	37							
	28/7/65	1·03	49	3·3	68	32							
	4/3/66	0·76	36	4·3	88	60							
	10/5/66	0·76	36	5·3	109	56	7·0	144	67	21·5	98	4·75	106
	7/7/66	1·78	85	5·2	106	38							
	30/9/66	0·65	31	3·7	76	47	6·0	122	66	21·9	99	4·8	107
8	12/5/66	0·59	28	3·9	92	40	5·8	136	60				
	23/6/66	0·38	18	4·4	103	60	5·65	133	80	16·1	85	4·0	90
	21/7/66	0·43	20	4·2	99	38							
	4/8/66	0·59	28	4·3	101	44				18·3	96	4·5	101
9	15/3/66	0·98	35	4·4	83	48	8·5	159	73				
	22/3/66	1·51	54	5·5	103	46				17·7	91	4·3	119
	10/5/66	1·99	71	4·9	91					20·2	106	4·6	128
	10/5/66	1·95	70	5·2	98	42				19·2	98	3·7	103
	9/9/66	0·65	23	4·2	79	61				22·2	114	5·7	156
	9/9/66	1·72	61	5·3	99	44	6·4	120	55				
	29/3/67	1·13	40	4·5	89	53	6·0	112	39				

Carbon Monoxide Transfer Factor.—The single breath T_{LCO} was also virtually normal and independent of the variation in F.E.V.$_1$ for both groups of patients (Fig. 2 and Table II) except for a slight reduction again when the F.E.V.$_1$ was below about 40% of the expected normal for the patients. The latter effect, however, is simply dependent on the rise in residual volume measured by helium dilution, already mentioned, and disappears when T_L/V_A is plotted against F.E.V.$_1$. In marked contrast with the normal values of T_{LCO} and T_L/V_A in patients with asthma are the low values in 13 of the 15 patients with relatively fixed and severe air-flow obstruction and radiological evidence of emphysema (Fig. 3).

Arterial Blood and Expired Gases.—Table III shows the arterial blood and expired gas studies (in eight of the nine patients we studied) in relation to the F.E.V.$_1$ at the start of the arterial blood collection and after bronchodilatation in the case of five of these patients. The arterial oxygen tensions tended to vary in both groups directly in relation to the magnitude of the F.E.V.$_1$ (Fig. 4) and increased with the rise in F.E.V.$_1$ in five patients after orciprenaline was given. There again appeared to be no difference between the clinical type of asthma in this respect. The lowered oxygen tension was associated with a raised A-aDO_2 in both groups (Table III) and with an increase in the estimated venous admixture. Both A-aDO_2 and the venous admixture tended to fall after orciprenaline was given.

The arterial carbon dioxide tension was the only measurement which showed a difference between the two clinical types of asthmatic patients (Fig. 5) in that it tended to be normal or below normal with group 1 patients with extrinsic asthma, but

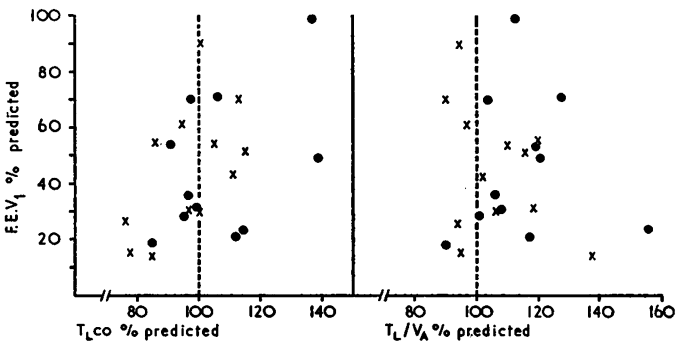

FIG. 2.—F.E.V.$_1$ (% predicted) plotted against T_{LCO} and T_L/V_A (both % predicted) in asthmatic patients.

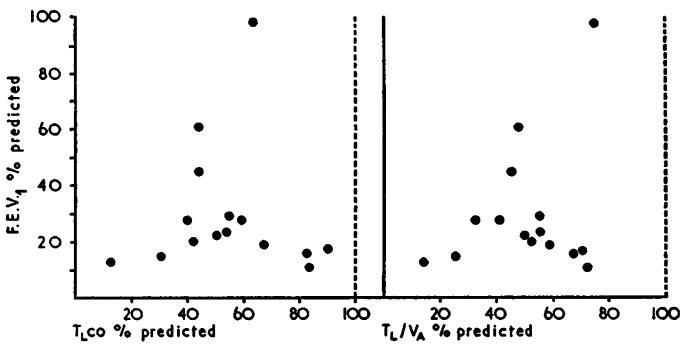

FIG. 3.—F.E.V.$_1$ (% predicted) plotted against T_{LCO} and T_L/V_A (both % predicted) in 15 patients with emphysema.

TABLE III.—*Blood Gas Studies*

Case No.	Date	F.E.V.$_1$ (l.)	F.E.V.$_1$ (% pred.)	V_D/V_T	Pa_{O_2} (mm. Hg)	Sa_{O_2} (%)	pH	Pa_{CO_2} (mm. Hg)	A-aDO_2 (mm. Hg)	Plasma HCO_3 (mEq/l.)	Estimated Venous admixture (%)
						Group 1					
1	24/3/66	0·48	16	0·49	68	93	7·41	39	38	25	32
3	5/7/66	1·73	64	0·21	77	95	7·41	29	33	18	20
4	7/6/66	0·75	27	0·32	70	95	7·45	31	45	21	32
	22/6/66	1·13	40	0·50	80	96	7·38	38	23	22	15
5	14/6/66	1·73	45	0·45	85	97	7·43	31	30	20	16
	*14/6/66	1·94	50	0·41	89	97	7·42	37	21	24	11
						Group 2					
7	3/10/66	0·49	23	0·44	56	90	7·41	48	25	30	35
	*3/10/66	0·59	28	0·38	63	92	7·40	47	19	29	25
8	23/6/66	0·36	18	0·28	78	95	7·40	43	33	26	20
	18/10/66	0·78	37	0·34	66	94	7·41	39	31	25	28
	*18/10/66	1·13	55	0·32	71	94	7·41	40	30	25	25
9	29/3/66	1·13	40	0·43	79	96	7·44	40	28	27	18
	*29/3/66	1·43	51	0·45	96	97	7·43	34	18	23	9
6	13/12/66	1·25	36	0·41	74	95	7·43	40	16	27	13
	*13/12/66	1·90	54	0·40	78	96	7·43	37	24	25	17

Sa_{O_2} = Arterial oxygen saturation.
* = After bronchodilatation with orciprenaline.

normal or above in group 2 patients. In both groups the $Paco_2$ tended to rise as the F.E.V.$_1$ fell.

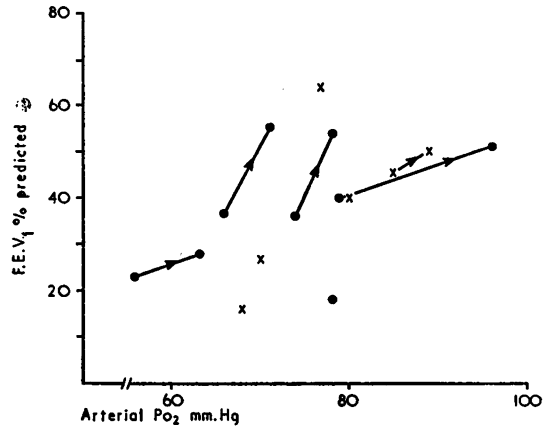

FIG. 4.—F.E.V.$_1$ (% predicted) plotted against Pao_2 (mm. Hg) in asthmatic patients. Arrows indicate change after bronchodilatation.

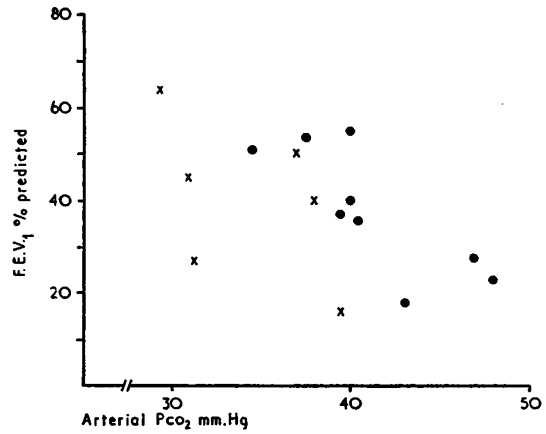

FIG. 5.—F.E.V.$_1$ (% predicted) plotted against $Paco_2$ (mm. Hg) asthmatic patients.

Discussion

Changes in Pulmonary Function

Though this is a small group, we took great care to select only definite examples of widely variable spasmodic asthma and to exclude patients who had chronic bronchitis. Their lung volumes measured by the body plethysmograph showed in practically all patients hyperinflation of the lungs, which was relatively constant and present even in mild airways obstruction, as judged by the F.E.V.$_1$, and which did not materially increase with increasing air-flow obstruction. The helium dilution appears to have resulted in underestimation of the patients' lung volumes, presumably because of some very poorly ventilated areas in the lungs which failed to dilute the helium in the equilibration time we used. Woolcock and Read (1966) found bigger helium-dilution values with a prolonged equilibration time of up to 20 minutes. We found such prolonged studies distressing to patients, and believe that the difference between the lung volumes measured with the shorter helium equilibration time and those measured by plethysmography to be of interest as a way of estimating the size of the very poorly ventilated areas.

In general the F.E.V.$_1$ is well related to the severity of symptoms in patients with asthma. There are, however, instances when patients appear to have changed symptomatically without a corresponding change in the F.E.V.$_1$. Woolcock and Read (1966) have suggested from their measurements of the subdivisions of the total lung capacity that in exacerbations of asthma the resting respiratory level may be raised to such an extent that the resting volume (F.R.C.) may be greater than the total volume the patient can reach voluntarily after recovery, and that the decline in F.E.V.$_1$ which normally accompanies airways narrowing might not take place as the patient hyperinflates his lungs, masking the airways-narrowing. In general our measurements of the F.R.C. (Table II) in relation to the T.L.C. support their view, though in our group of patients the T.L.C. seems to remain consistently higher as the F.E.V.$_1$ improves. Thus objective assessment of improvement in asthma really requires measurement of lung volumes as well as the more easily performed F.E.V.$_1$ measurements. But for general purposes there is no better method of assessing change in asthma than the F.E.V.$_1$, provided both the absolute F.E.V. and the F.E.V./V.C. ratio are considered (Thomson and Hugh-Jones, 1952).

We found that the single breath CO transfer factor remained remarkably normal in all grades of severity of asthma, especially when it is recorded as the T_L/V_A. Our results agree with those of Kanagami *et al.* (1961). By contrast, in studies using the steady state technique T_LCO may occasionally be low in asthma, especially in severe histamine-induced asthma (Bates and Christie, 1964), since this method is more sensitive to ventilation-perfusion abnormalities in the lung (Kreukniet and Visser, 1962) than is the single breath method (Piiper and Sikand, 1966). The results shown in Figs. 2 and 3 suggest to us that the single breath CO transfer is a satisfactory method of differentiating air-flow obstruction caused by asthma from that associated with emphysema.

The fall in arterial oxygen tension with only moderate reduction of the F.E.V.$_1$ agrees with the findings of Tai and Read (1967), and means that these patients are in a potentially precarious state if their asthma suddenly gets worse. It is against the general concept that asthma is relatively harmless and does not cause blood-gas disturbance, which probably arises because these patients, unlike many of those with exacerbations of chronic bronchitis, tend not to be cyanosed but to maintain their arterial saturation by alveolar hyperventilation in spite of a large alveolar-arterial oxygen tension difference (Table II). In all the group 1 patients with extrinsic asthma the $Paco_2$ tended to be low because of this increased alveolar ventilation. The tendency towards a low plasma bicarbonate in relation to the *p*H and $Paco_2$ (Table III) suggests that the hyperventilation was not just a transient one, during the studies, but was of long duration. Though Tai and Read do not comment in detail about the $Paco_2$ our results agree with theirs, and we believe from these studies and from others on patients in severe status asthmaticus (to be published) that continuous monitoring of the $Paco_2$ in young asthmatics in severe asthma is of profound importance. The $Paco_2$, initially low, rises to normal values and then increases as their asthma becomes more severe and they are no longer able to maintain their hyperventilation and relatively normal arterial oxygen saturation. In other words, a rise of $Paco_2$ in such patients heralds a severe emergency when the Pao_2 may fall precipitately, and death can occur unless ventilation is achieved artificially. This may explain the findings of Jacoby (1966) of a high mortality in young asthmatics with really severe asthma.

The mechanism of the hypoxaemia in asthma is the maldistribution of the ventilation/blood-flow ratios in the lungs which is shown in the tendency to high physiological dead space (V_D/V_T ratios) and large A-aDo_2 shown in Table III. An increased venous admixture effect would result from the continued perfusion of poorly ventilated lung, and this has been shown by Ledbetter *et al.* (1964) to occur in asthmatic children. The increase in physiological dead space is more difficult to explain; the two measurements are, however, not entirely independent, so that an increase in venous admixture will always be accompanied by some increase in dead space (Severinghaus and Stupfel, 1957). An increased inequality of ventilation/blood-flow ratios in asthma has also been demon-

strated by the single breath method of West *et al.* (1957); the original authors reported this abnormality in one patient, and this result was confirmed in 1962 in a further 20 asthmatic patients (Pride, unpublished). It seems, therefore, that the presence of ventilation-perfusion imbalance does not imply a fixed structural abnormality in the lungs.

Bronchodilatation with orciprenaline produced a rise in Pa_{O_2} and a fall in the estimated venous admixture in the five patients studied. It is interesting that Halmagyi and Cotes (1959), Field (1967), and Knudson and Constantine (1967) have all described a fall in Pa_{O_2} following bronchodilatation with isoprenaline. Halmagyi and Cotes described cases with more severe and fixed airways obstruction, but in the other two studies the variability of air-flow obstruction was similar to that of our patients. The difference between our results with orciprenaline and those of others with isoprenaline is probably related to the greater cardiovascular effects of isoprenaline (Shanks *et al.*, 1967), which may lead to disturbance of the ventilation/blood-flow balance of the lungs.

Clinical Types of Asthma

We found no differences in lung volumes and gas transfer between patients with extrinsic and intrinsic asthma in spite of selecting extreme cases of the two groups (Rackemann, 1947). The $Paco_2$ was the only test of lung function that we found to be different in the two groups. Though $Paco_2$ was less than 50 mm. Hg in all patients, there was a higher average $Paco_2$ in the intrinsic than in the extrinsic group. The two groups of asthmatics are of different ages, but we do not think that this is an age effect.

Comparison of Functional Changes

The clinical differentiation between asthma, chronic bronchitis, and emphysema, all of which give rise to air-flow obstruction, is notoriously difficult, and many patients may have all three conditions to a greater or less degree. Nevertheless, by careful selection of extreme examples, with use of independent assessment of radiological and clinical features, it is possible to select individual patients whose main lesion is one of these three conditions. Fletcher *et al.* (1963) selected a few patients who had only gross emphysema and compared them with others who had only gross chronic bronchitis. In a subsequent paper (Burrows *et al.*, 1966) they substantiated their separation of these two conditions by post-mortem studies. We, similarly, tried to select patients who had only spasmodic asthma, and believe, at least in our extrinsic group 1, we succeeded. We tried with the intrinsic group too, but the dividing line between chronic bronchitis and intrinsic asthma is less well marked, and many subjects with chronic bronchitis have increased sensitivity in inhalant substances (Vries *et al.*, 1962), and both asthma and chronic bronchitis can produce excess bronchial secretion of mucus and coughing. However, our patients had no suggestion of bronchitis when they were in remission. We therefore feel justified in a tentative comparison of the functional lesion of asthma alone (at least for the extrinsic group) with that reported for chronic bronchitis and for emphysema alone.

We have summarized in Table IV the chief functional contrasts between these three types of lesion (asthma, chronic bronchitis, and emphysema) which may be helpful in assessing their importance in patients who have air-flow obstruction of mixed causation. The Table is valid only for a comparable degree of moderately severe air-flow obstruction—that is, for patients with an $F.E.V._1$ of the order of 1 litre. It will be seen that an increase in the ratio of residual volume to the total lung capacity simply indicates a state of inflation of the lungs, and is present in all three types of lesion and does not indicate the presence of anatomical emphysema. The best single test to aid in assessing the presence of emphysema is a reduction in the carbon monoxide transfer factor as shown by a lowered T_L/V_A, or this expressed as the "K_{CO}" (McGrath and Thomson, 1959). Only in chronic bronchitis is the alveolar and arterial Pco_2 commonly raised, though it may rise in severe asthma or in patients with asthma of the clinically intrinsic type. It is of interest that the presence of heart failure seems to be related to the tendency for the Pco_2 to rise from relative alveolar hypoventilation. Asthma itself is characterized by having the definite ventilation–perfusion imbalance characteristic of bronchitis but compensated by alveolar hyperventilation so that the oxygen saturation remains less affected than in the case of bronchitis.

TABLE IV.—*Summary of Differences Between Spasmodic Asthma, Chronic Bronchitis, and Emphysema in "Pure" Examples of Each for Comparable Air-flow Obstruction*

	Emphysema	Chronic Bronchitis	Asthma
Clinical:			
Rhonchi	Absent	Present	Present
History of heart failure or E.C.G. changes	Absent	Present	Absent
Lung-function tests:			
F.E.V./V.C.	Very low	Low	Variable, low in exacerbations
R.V./T.L.C.	Raised	Raised	Raised
Single breath CO transfer/V_A	Decreased	Normal	Normal
Arterial O_2 saturation	Normal	Decreased	Normal
Arterial Pco_2	Normal or reduced	Raised	Normal or reduced
Inequality of V_A/Qc	Moderate	Marked	Marked

We believe that by clinical and radiological assessment, together with measurement of the $F.E.V._1$, the CO transfer, and the arterial Pco_2, it is usually possible to assign the extent to which asthma, bronchitis, and emphysema each contributes to the air-flow obstruction of a patient and to treat the patient accordingly.

Summary

Nine asthmatic patients, five of the extrinsic and four of the intrinsic type, were studied on repeated occasions. Measurements of their total lung capacity and carbon monoxide transfer showed no difference between the two groups. Carbon monoxide transfer factor remained normal despite wide variation in the asthmatic state as assessed by the $F.E.V._1$.

Helium dilution underestimated the total lung capacity in severe asthma, and its measurement by whole body plethysmography showed it to be greater than the predicted normal, in both mild and severe asthma. Arterial oxygen tension was reduced in proportion to the severity of the airways obstruction and rose after bronchodilatation with orciprenaline.

Carbon dioxide tension was normal or low in all these patients, but was persistently higher in the intrinsic than in the extrinsic group.

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Some Clinical Aspects of Respiratory Intensive Care

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In a recent paper (Campbell *et al.*, 1967) the general problems involved in the organization of a respiratory intensive care unit in the Glasgow Royal Infirmary were discussed. In addition the various categories of patients treated in the unit were outlined. This communication represents a more detailed analysis of 202 of these patients suffering from respiratory insufficiency after elective and emergency surgery.

Postoperative Respiratory Problems

Two hundred and two patients were treated in the intensive care unit after elective or emergency surgery. Though a proportion of them could be classified more properly as "24-hour recovery cases" they were of necessity admitted owing to a shortage of routine postoperative recovery facilities in this hospital. Nevertheless, the average length of stay was 4.1 days, a figure which suggests that on the whole these patients would have required prolonged postoperative care even if immediate recovery facilities had been available.

TABLE I.—*Analysis, According to Age, of* 131 *Elective Surgical Patients who Developed Postoperative Respiratory Insufficiency. Ratio of Males to Females* = 1.7 : 1. *Overall Survival Rate: Males* 85.6%, *Females* 78.7%

Decade	No. of Patients		% Survival	
	Male	Female	Male	Female
1	1	1	100	100
2	1	—	100	—
3	—	1	—	100
4	3	—	100	—
5	9	6	89	100
6	20	15	95	67
7	32	12	75	67
8	18	10	89	80
9	—	2	—	50
10	—	—	—	—

It is of some interest to compare those patients admitted after elective surgery with those admitted after emergency surgery. The latter group might be expected to show considerable differences from the elective cases in that, as a general rule, there was little time or opportunity preoperatively to carry out the most thorough respiratory investigations or preparatory therapy. Tables I and II compare the two groups of patients from the point of view of distribution of ages. The numbers of patients, both male and female, are shown, together with the percentage survival rates for each decade. The overall survival rates are better for the males in both elective and emergency categories. The ratio of males to females is slightly higher in the emergency cases. The Tables otherwise show a strikingly similar distribution of patients, with the bulk of cases occurring in the fifth to eighth decades.

TABLE II.—*Analysis, According to Age, of* 71 *Emergency Surgical Patients Who Developed Postoperative Respiratory Insufficiency. Ratio of Males to Females* = 2.5 : 1. *Overall Survival Rate: Males* 68.6%, *Females* 50%

Decade	No. of Patients		% Survival	
	Male	Female	Male	Female
1	—	—	—	—
2	1	—	100	—
3	—	—	—	—
4	1	1	100	100
5	4	4	50	50
6	13	3	77	100
7	23	9	61	44
8	7	2	71	0
9	3	—	67	—
10	—	—	—	—

Tables III and IV (131 elective cases and 71 emergency cases) indicate the major disturbance of normal function in each patient, though all presented initially as respiratory problems. The main problems can be classified under metabolic, cardiovascular, pre-existing chronic lung disease, and those involving the relaxant drugs. Where more than one major disorder was identified in one patient, the individual is classified under each heading.

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