

Lung volumes and distensibility, and maximum respiratory pressures in thyroid disease before and after treatment

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Freedman, S (1978). *Thorax*, 33, 785–790. **Lung volumes and distensibility, and maximum respiratory pressures in thyroid disease before and after treatment.** Lung volumes, static pressure volume curves of the lung, and maximum respiratory pressures were measured in six patients with thyrotoxicosis and three with myxoedema before and after treatment. After treatment three of the thyrotoxic patients had increases in vital capacity of the same order as previously reported, but in contrast to previous reports, the lung volume changes were not associated with, nor due to, concomitant changes in respiratory muscle performance. Static pulmonary compliance increased in four of the six patients. The initial findings were more in keeping with the presence of pulmonary congestion. Only one of the myxoedematous patients had any significant increase in vital capacity after treatment, and in her case this was clearly attributable to increased inspiratory muscle force.

A reduced vital capacity (VC) in patients with thyrotoxicosis was first noted in 1917 by Peabody and Wentworth who examined seven such patients and found that two of them had a VC less than 80% of predicted normal. This observation was confirmed by Rabinowitch (1923) and Lemon and Moersch (1924). The reduction in VC is reversible with successful treatment and is associated with, and attributed to, weakness of the respiratory muscles with reduced maximum respiratory pressures (Stein *et al*, 1961; Wasserman 1962). The only previous measurements of static pulmonary compliance were by Massey *et al* (1967) who found that in most cases it was normal although reduced in those patients with the biggest reductions in VC. Stein *et al* (1961) reported big reductions in dynamic compliance in contrast to McIlroy *et al* (1956) who found it to be normal in two patients.

In myxoedema, uncomplicated by obesity or respiratory disease, VC has been found to be normal (Wilson and Bedell, 1960).

The objects of the present study were to measure the elastic properties of the lungs and the performance of the respiratory muscles in thyrotoxicosis and myxoedema before and after treat-

ment. A brief report has been published (Freedman, 1977).

Methods

Six patients with thyrotoxicosis and three with myxoedema were studied. They all agreed to take part in the experiments after it had been explained that none of the procedures formed a necessary part of their treatment. Some clinical and biochemical details are given in the table. Initial studies were carried out within a week or two of the diagnosis being established and before specific treatment was started, although the four patients (Wa, Wi, De, Lu) who presented with fast atrial fibrillation or cardiac failure, or both, received digoxin or diuretics and had a period of bed rest before the initial studies. In all cases this successfully reversed any clinical or radiological signs of cardiac failure before the initial studies.

The patients were studied again three to four months later after appropriate treatment (carbimazole or l-thyroxine) and when they were clinically and biochemically euthyroid. Patient De was studied three times—initially on admission to

hospital when she was in cardiac failure and on a further two occasions as described above. The only patient with an associated disease that affected his results was Wa who had moderately severe airways obstruction due to chronic bronchitis.

At each visit, lung volumes, static expiratory pressure-volume curves (PV curves) of the lung, and maximum respiratory pressures were measured.

Forced expiratory volume in one second (FEV_1) and VC were measured on a Vitalograph dry spirometer, with the patients seated. Residual volume was measured by closed circuit helium dilution. Duplicate measurements were made and the results required to agree within 10%. Oesophageal pressures were measured using 10 cm long oesophageal balloons mounted on polyethylene catheters (Milic-Emili *et al*, 1964) with the tip of the balloon being passed to a depth of 40–45 cm from the nares. The exact depth to which the balloon was passed at the first study was noted and was used again at the second visit. Balloon technique was otherwise as described by Milic-Emili *et al*, and pressures were measured using a Hewlett-Packard 267B transducer and displayed on the same manufacturers' four-channel recorder together with lung volume changes that were measured using a water spirometer. Static expiratory PV curves were measured by sequential interruption of airflow at the mouth during an expiration from total lung capacity (TLC). Each expiration was preceded by two vital capacity breaths. Sufficient measurements were taken to obtain at least three PV curves that agreed closely, and these were averaged by eye. In two cases (De and Lu) compliance was measured during a slow but uninterrupted expiration because the patients could not co-operate (quasi-static).

Maximum inspiratory and expiratory pressures were measured from the oesophageal balloon, using pleural-to-atmospheric pressure differences. For these measurements, balloon volume was increased to 1 ml. Measurements were made at various lung volumes until the maximum pressures that could be sustained for at least two seconds were obtained with the patients either sucking or blowing against a closed tap. In practice the biggest pressures were found at volumes close to FRC, and it was found helpful to have a pinhole in the mouthpiece and to remove the noseclip during these manoeuvres. Normal values were taken from Cotes (1975).

Results

Some anthropometric data, thyroid function tests,

and results before and after treatment are presented in the table.

Of the six thyrotoxic patients, only three had appreciable increases in VC with successful treatment. These improvements in VC were achieved largely at the expense of residual volume in De and by increases in TLC in Wi and Jo. Changes in maximum respiratory pressures in all the thyrotoxic patients were inconsistent and unrelated to changes in thyroid function or lung volumes. Generally, maximum pressures were below the normal ranges of Black and Hyatt (1969) even when the patients were euthyroid.

PV curves of the thyrotoxic patients are shown in fig 1. In the three patients who increased their VC (upper 3 panels) successful treatment was accompanied by a shift of the curve to a higher lung volume and with a steeper slope. The slopes were assessed by measuring static compliance between FRC and 0.5 l above it before treatment and at the same lung volume after treatment. There were significant increases in compliance in four of the six patients and these were clearly related to changes in VC (fig 2) excepting Wa in whom the VC was probably more dependent on his airways obstruction than anything else. In De, a quasi-static PV curve was obtained shortly after admission when she was in congestive and left ventricular heart failure. The three PV curves on this patient show a progressive increase in TLC, steepening of slope, and reduction in recoil pressure at TLC.

Of the three myxoedematous patients, only one (Lu) showed any changes between the first and second measurements (fig 3 and table). She had a big increase in TLC (1.08 l) and VC (0.55 l) with RV/TLC ratio staying almost the same. Maximum respiratory pressures were increased when she was euthyroid, as was recoil pressure at TLC, although the slope of the PV curve was unchanged.

Discussion

The initial VC in the six thyrotoxic patients averaged 81% of predicted normal, which is comparable with the mean pretreatment value reported by Stein *et al* (1961) (87%), Wassermann (1962) (88%), and Massey *et al* (1967) (76%). Three of these six patients showed improvements in VC after treatment comparable with those reported by Stein *et al* and by Wassermann, which were on average 0.40 l and 0.26 l respectively, while Richards *et al* (1953) found a mean increase of 0.27 l in 10 patients.

The previous workers found that there were concurrent increases in maximum respiratory pres-

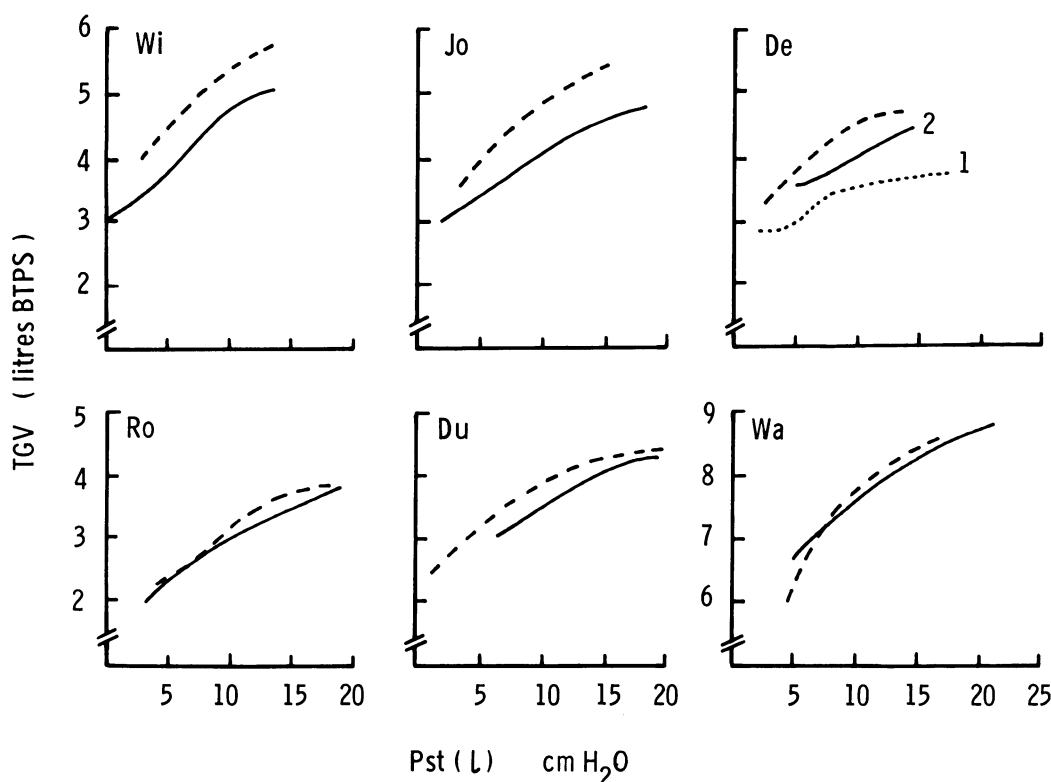


Fig 1 Static expiratory pressure-volume curves in thyrotoxic patients before — and after - - - - - treatment. In patient De, two sets of measurements were made before treatment; a quasi-static measurement (no 1) when she was in cardiac failure and a static curve (no 2) when the failure had been resolved but before specific treatment.

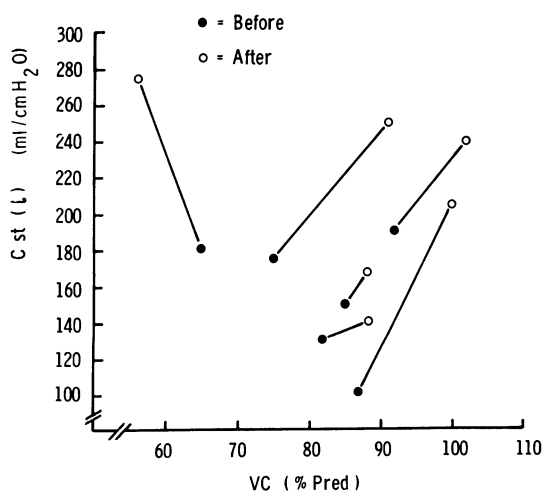


Fig 2 Relationship between changes in vital capacity and changes in static pulmonary compliance with treatment in thyrotoxic patients.

tures and consequently attributed the fall in VC in thyrotoxicosis to a myopathy affecting the respiratory muscles. In the present study, changes in maximum respiratory pressures were small and inconsistent and clearly unrelated to changes in VC. Additional evidence against muscle weakness as the cause of the low initial VCs in the present study is provided by the static lung PV curves.

If there had been significant improvements in respiratory muscle performance with successful treatment of thyrotoxicosis there should have been big increases in static recoil pressures at TLC, together with increased TLC and static compliance (Gibson and Pride, 1976; Gibson *et al*, 1977), but pressures at TLC were the same or smaller after treatment.

An alternative explanation for the changes in lung volume and the PV curve is that they were due to pulmonary vascular engorgement. The pre- and post-treatment PV curves closely resemble those of patients with cardiac failure compared

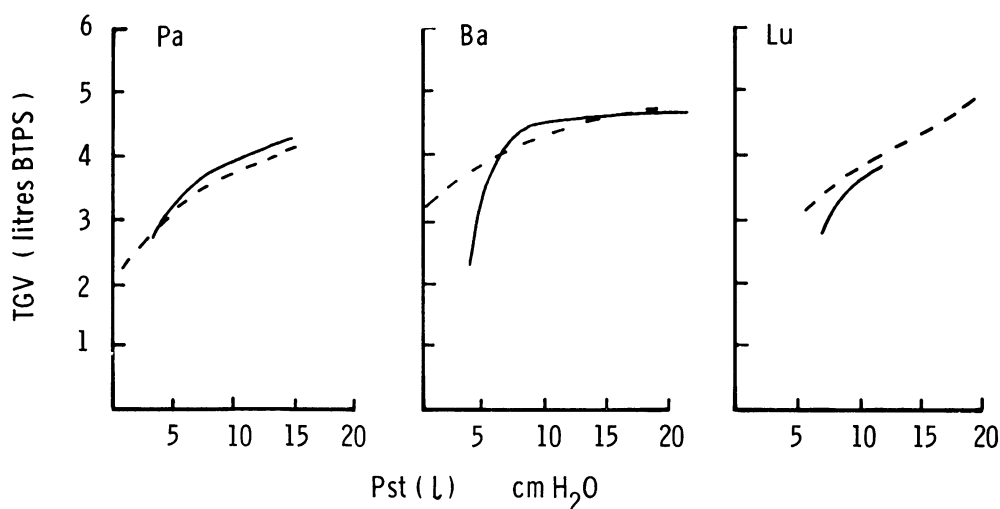


Fig 3 Expiratory pressure-volume curves in the myxoedematous patients before — and after ---- treatment. The pretreatment curve in Ba is quasi-static; all other curves are static.

Table Lung function in patients with thyroid disease

Name	Sex	Age	Height (cm)	Free thyroxine Index	FEV ₁	VC	TLC	RV	C _{St} (l) ml/cm H ₂ O	Max pleural pressures (cm H ₂ O)		
										Insp	Exp	
A Hyperthyroid patients												
Ro	F	46	147	17.1 8.7	66 85	82 88	98 102	145 140	130 140	72 70	62 27	
Wa*†	M	63	175	24.0 5.2	46 45	65 56	130 125	261 262	180 275	44 46	52 120	
Wi*	F	69	167	27.5 8.7	103 110	92 102	96 110	102 123	190 240	40 42	42 30	
Du	F	68	155	27.1 4.7	97 106	85 88	101 103	131 134	150 167	20 38	40 60	
Jo	F	53	168	30.5 6.7	70 84	75 91	90 102	118 120	175 250	40 56	30 60	
De*	F	56	157	27.1 6.1	(45) 78 88	(61) 87 100	(85) 101 107	(132) 130 122	102 192	38 34	33 50	
B Hypothyroid patients												
Pa	F	62	152	2.9 17.6	106 102	106 101	114 107	132 125	290 220	40 80	35 20	
Ba	F	66	160	1.2 8.7	91 81	95 113	106 108	163 141	— 135	41 42	16 44	
Lu*†	F	72	176	2.4 10.2	64 77	75 91	75 96	60 84	220 220	15 32	27 35	

*In cardiac failure at time of presentation.

†In atrial fibrillation at time of presentation.

For all patients, data before and after treatment are given in each column, the first of each pair of figures being pretreatment.

All lung volumes reported as % predicted normal values. Normal range for free thyroxine Index is 4.2–15.0.

Figures in parenthesis for patient De refer to first study on admission when she was in congestive heart failure. The second study was done a week later after treatment with digitalis and diuretics.

with normal subjects reported by Brown *et al* (1954) and those of patients with atrial septal defect and pulmonary hypertension reported by De Troyer *et al* (1977). Von Basch is credited by Gibson and Pride (1976) with first describing the effects of vascular engorgement on the PV curve—namely, a reduction in lung volumes and distensibility above FRC and a reduced recoil pressure with slightly increased volumes below FRC. I was unable to obtain many measurements below FRC but the size and direction of the changes in the PV curve is otherwise compatible with this explanation, which has the additional merit of fitting

in with the known effects of thyrotoxicosis on the pulmonary circulation, which are to increase pulmonary blood flow with a proportional increase in pulmonary artery pressure (Bishop *et al*, 1955).

Although two of the three patients with appreciable increases in vital capacity were in cardiac failure at the time of presentation, changes in static compliance were not confined to these two patients and, moreover, the clinical signs of failure had resolved with treatment before the initial studies. Thus if pulmonary congestion was the explanation for the changes in the PV curve it can be present without overt signs of cardiac

failure. Acute pulmonary vascular engorgement in normal subjects is also reported to produce a fall in dynamic compliance (Bondurant *et al*, 1957).

Another possible explanation for the changes in compliance and in the PV curves is that they result from changes in tissue elastic properties or in pulmonary surface forces induced, in some way as yet undefined, by the thyrotoxicosis. There is no available evidence about this possibility, but nothing in the present or previous results excludes it.

The differences between the present findings and those of previous workers, especially Stein *et al* (1961) and Wassermann (1962) who presented strong evidence in favour of a myopathy as the cause of the low initial VC, may be because the patients in the present study were on the whole older than in the previous series, although there was some overlap, and in Wassermann's study the five patients aged 60 or over had similar findings to the younger patients.

It is difficult to compare degrees of toxicity due to different methods of assessment, but in any case, apart from Rabinowitch (1923), all other workers have failed to show a correlation between degree of toxicity and vital capacity, or other lung volumes.

I examined this question further by pooling all data from the present and previous studies in which results in individual patients are given. After standardising measurements in terms of percentage of normal, I again found no correlation between degree of thyrotoxicosis and VC or compliance (pooling static and dynamic measurements).

The only myxoedematous patient whose VC improved after treatment (Lu) in fact showed the changes that might have been expected in the thyrotoxic patients. Successful treatment produced a pronounced increase in TLC, in recoil pressure at TLC, and in maximum inspiratory pressure. These changes are clearly due to an improvement in respiratory muscle force. This patient was not obese.

A previous report of two myxoedematous patients with myopathies sufficient to produce very low VCs and to precipitate ventilatory failure in fact concerned patients who were also grossly obese (Massumi and Winnacker, 1964). Wilson and Bedell (1960) concluded that, on average, lung volumes were normal in myxoedema uncomplicated by obesity or respiratory disease, but of 13 patients they studied before and after treatment, four had initial values of VC below 80% of predicted normal and, of these, three had normal VCs after treatment. They did not measure any maximum respiratory pressures, but there was no clear indi-

cation from their measurements of maximum inspiratory flow rate of an improvement in respiratory muscle performance with treatment. Additional information is provided by Weg *et al* (1965) who reported one obese myxoedematous patient in respiratory failure but with normal lung volumes and by Burack *et al* (1971) who found no change in VC after treatment in five patients.

It thus appears that some non-obese patients with uncomplicated myxoedema may have a low VC that improves with treatment while others have normal lung volumes. The low VC is certainly attributable to respiratory muscle weakness in patient Lu and this would be a feasible mechanism for the reduction in VC previously reported, but the evidence is inconclusive. The position is certainly less clearly defined than has been stated (Bates *et al*, 1971), both for myxoedema and thyrotoxicosis. The present results in thyrotoxicosis support the view of Lemon and Moersch (1924): "As to the primary fundamental physicochemical cause of the decreased vital capacity in hyperthyroidism, we are still uncertain and must await further investigation. However, we believe the secondary and direct cause is the cardiac inefficiency which arises from the primary source, the thyroid."

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