Thorax 1983;**38**:595–600

Postural relief of dyspnoea in severe chronic airflow limitation: relationship to respiratory muscle strength

S O'NEILL, DS McCARTHY

From the Section of Respiratory Diseases, University of Manitoba, Health Sciences Centre, Winnipeg, Manitoba, Canada

ABSTRACT Maximal static inspiratory and expiratory pressures (Pi_{max} and Pe_{max}) were measured in six different positions in 40 patients with advanced chronic airflow limitation and in 140 normal subjects to determine whether posture influences respiratory muscle strength. Patients with chronic airflow limitation were studied on days 1 and 5 of an acute exacerbation. There was no postural effect on maximal static pressures in the normal subjects. We divided our patients with chronic airflow limitation into "moderate" and "severe" groups on the basis of a Pi_{max} in the standing position greater or less than 35 cm H_2O. The seated leaning-forward position was the preferred posture in 22 of the 23 "severe" patients and 13 of the 17 "moderate" patients. Pi_{max} was greater in the seated leaning-forward position than in the other positions studied ($p < 0{\cdot}001$) on days 1 and 5 in the "severe" patients and ($p < 0{\cdot}05$) on day 5 in the "moderate" patients. Posture had no influence on Pe_{max} in patients with chronic airflow limitation. There was a significant improvement in both Pi_{max} ($p < 0{\cdot}01$ for the "severe" group and $p < 0{\cdot}05$ for the "moderate" group) and Pe_{max} ($p < 0{\cdot}01$ for both groups) between days 1 and 5. The seated leaning-forward position was the optimum posture for the patients to generate maximum inspiratory pressures and to obtain greatest subjective relief of dyspnoea.

Patients with severe chronic airflow limitation (synonyms chronic obstructive airways disease, chronic obstructive lung disease) have reduced inspiratory muscle strength.[1] Such patients may experience a reduction in dyspnoea by assuming a particular posture.[2] The present study was undertaken to confirm this observation in a large group of patients and to characterise further the relationship between posture and other clinical and physiological findings—in particular maximal static respiratory pressures as an index of respiratory muscle strength—in patients with severe chronic airflow limitation. In addition we wished to determine the effect of a period of hospital treatment on the findings.

Address for reprint requests: Dr S O'Neill, Section of Respiratory Diseases, Department of Medicine, University of Manitoba, Health Sciences Centre, 700 William Avenue, Winnipeg, Manitoba R3E OZ3, Canada.

Accepted 16 March 1983

Methods

Maximal static pressures were measured with two diaphragm pressure gauges, one recording negative and the other positive pressure by the method of Black and Hyatt.[3] The gauges were calibrated with a differential pressure transducer (Statham PM-131, TC; Statham Instruments, Hato Rey, California); their recorded pressures were within ± 5% of transducer pressure up to 300 cm H_2O expiratory pressure and 160 cm H_2O inspiratory pressure.

One hundred and forty normal adults were tested to establish a normal range and to determine whether postural changes affected maximal pressures in normal subjects. All subjects were Caucasian and comprised 10 men and 10 women in each decade from 20 to 80 years and in the age group 80–85 years. All were symptom free, had a normal chest radiograph, and spirometric values[4] within the predicted normal range. One hundred and sixteen of the subjects were patients on general medical and surgical wards; the remainder were healthy physicians, medical students, and laboratory technicians. Thirty of the men and 22 of the women were smokers. There was no correlation (r = 0·221; p > 0·05) between smoking history and the static pressures generated.

Measurements were made in six positions—standing erect, supine, seated erect, seated leaning forward at a 45° angle, and right and left lateral decubitus. All subjects wore nose clips and pressed their lips tightly against the mouthpiece during the pressure measurements to prevent an air leak. They were instructed not to suck and to keep their hands closely applied to their cheeks. Maximal inspiratory pressure (Pi_{max}) was measured at residual volume (RV) and maximal expiratory pressure (Pe_{max}) at total lung capacity (TLC). The pressures recorded were maintained for at least one second. The determinations were repeated until three technically satisfactory measurements were obtained and the highest value of each was used. The order of positions in which the pressures were measured was varied in random sequence for each age group.

Forty patients with previously diagnosed chronic airflow limitation on the basis of FEV_1 and FEV_1/FVC ratio always less than 60% of the predicted value and less than 10% improvement after bronchodilator were studied during the course of an acute exacerbation. The study had been previously approved by the hospital ethics committee. The patient group comprised 23 men and 17 women with a mean age of 69·4 years and a range of 44–84 years. Patients having steroid treatment or with pulmonary infiltrates were excluded from the study. The patients were studied on days 1 and 5 of their hospital admission after informed consent had been obtained. All patients complained of dyspnoea at rest in the upright posture on day 1 of the study.

The patients were studied in each of six positions: standing, seated erect, seated leaning forward, supine, and right and left lateral decubitus. They were allowed to rest three minutes in each position before being tested. The following physical signs[5] were assessed in each position: (1) costal paradox with decrease in lateral diameter of costal margin on inspiration (Hoover's sign)[6]; (2) inward motion of the abdomen during inspiration; (3) tracheal descent with inspiration; (4) contraction cf the sternomastoids during inspiration.

These physical signs were observed and recorded as present or absent by one of us (S O'N) before measurement of static pressures. The patient's preferred posture and the sensation of dyspnoea or its relief in each position were recorded. To assess the sensation of dyspnoea and its relief or exacerbation, we adopted a category scale in which words describing increasing or decreasing degrees of breathlessness are linked to numbers from 0 to 10. The patients were asked to categorise their shortness of breath in each position as unchanged (4–6), slightly (3–4), moderately (1–3), or markedly (0–1) better; or slightly (6–7), moderately (7–9), or markedly (9–10) worse than the sensation in the standing erect posture, which was arbitrarily chosen as the reference posture and designated as 5 on the category scale. Only moderate or marked relief or exacerbation of the sensation of dyspnoea was classified as relief or exacerbation of dyspnoea. Maximum static inspiratory and expiratory pressures were measured in each position as described for the normal controls. No formal attempt was made to correlate Pi_{max} with the ability to expire fully to RV. Normal subjects and patients were, however, excluded from the study if by observation they appeared not to reach the desired volume (RV or TLC) before the pressure measurement. All patients had serum theophylline concentrations in the range 10–20 μg/ml on the days of testing. Serum potassium, magnesium, phosphate, and calcium concentrations were measured to exclude from study patients with an overt metabolic cause for respiratory muscle weakness.

Spirometric measurements[7] and plethysmographic lung volumes[8] in the seated erect posture were obtained on both days. Height and weight were recorded in all subjects and ideal weight was estimated from Metropolitan Life Insurance tables.[9] Radiological evidence of hyperinflation was taken to be present if the following three indices were present[10]: (1) the right hemidiaphragm was at or below the seventh rib anteriorly; (2) a vertical line to the top of the diaphragm from a line between the cardiophrenic and costophrenic sulci was less than 1·5 cm; (3) the diaphragmatic excursion between full inspiratory and expiratory films was less than 3 cm.

Data are reported as means ±1 SD and are expressed as absolute values or as percentages of predicted normal values. Results were analysed by Students t test for paired data, the χ^2 test, and standard least-squares linear regression analysis. To analyse the relationship between radiological indices of hyperinflation and the continuous variable Pi_{max}, measured on day 1 in the standing erect posture, we used linear contrast analysis.[11] The radiological abnormalities were graded into four categories: grade 0—absent; grade 1—one index present; grade 2—two indices present; grade 3—all indices present. For each grade of radiographic abnormality the mean Pi_{max} was calculated and the relationship between them was evaluated by one-way analysis of variance and the use of contrast to isolate the linear component of the relationship. A linear regression approach was applied to the individual data points

Results

The relationships of age to Pi_{max} and Pe_{max} in normal men and women in various age groups are presented in table 1, expressed as the mean ±2 SD. There were no significant differences between mean pressures in the six positions tested in the different age categories for either sex ($p > 0.05$). The average value for the individual coefficient of variation for duplicate determinations at one time was 8% for Pi_{max} and Pe_{max}. Ten women and 10 men were tested in the same manner on three consecutive days. There was no significant difference between the mean values for the pressures on the first day and those on the second and third days. The highest value for Pi_{max} and for Pe_{max} on the third day was less than 10% greater than the value on the first day in seven subjects and was unchanged or lower in 13 subjects, suggesting that the short-term learning effect is slight. The decline in maximum static pressures with age and the influence of sex—women generating about 70% of the values obtained by men—are similar to the findings of previous studies.[3]

We divided our patients with chronic airflow limitation into two groups on the basis of Pi_{max} as an index of inspiratory muscle strength, in the manner of Braun and Rochester.[12] A "severe" group was arbitrarily defined as those having a Pi_{max} value of

Table 1 *Maximal static pressures (means ±2 SD) in normal subjects in the seated erect posture**

Age group	*Pi_{max} (cm H_2O)*		*Pe_{max} (cm H_2O)*	
	Male	*Female*	*Male*	*Female*
20–29	118 ± 38	90 ± 24	225 ± 70	155 ± 63
30–39	116 ± 45	92 ± 28	230 ± 62	158 ± 59
40–49	120 ± 32	86 ± 22	222 ± 74	152 ± 66
(20–54)	(124 ± 44)	(87 ± 32)	(233 ± 84)	(152 ± 54)
50–59	108 ± 46	81 ± 25	214 ± 68	140 ± 52
(55–59)	(103 ± 32)	(77 ± 26)	(218 ± 74)	(145 ± 40)
60–69	101 ± 44	76 ± 24	198 ± 73	132 ± 46
(60–64)	(103 ± 32)	(73 ± 26)	(209 ± 74)	(140 ± 40)
(65–69)	(103 ± 32)	(70 ± 26)	(197 ± 74)	(135 ± 40)
70–79	99 ± 36	70 ± 26	184 ± 66	126 ± 42
(70–74)	(103 ± 32)	(65 ± 26)	(185 ± 74)	(128 ± 40)
80–84	94 ± 40	68 ± 22	176 ± 58	122 ± 44

*Figures in parentheses represent normal values of Black and Hyatt.[3] There were no significant differences between mean pressures in the six positions ($p > 0.05$) in the different age categories.

Table 2 *Maximal inspiratory pressure (Pi_{max}) and other lung function measurements (means ±1 SD) in patients with moderate and severe airflow limitation*

	Moderate group		*Severe group*	
	Day 1	*Day 5*	*Day 1*	*Day 5*
Pi_{max} (cm H_2O) standing	50·8 ± 5·9	61·5 ± 9·2	27·1 ± 7·7	36·1 ± 8·0
supine	50·6 ± 10·0	61·5 ± 9·3	30·2 ± 9·1	37·2 ± 7·4
seated erect	52·1 ± 11·3	61·7 ± 10·8	29·6 ± 10·5	36·7 ± 8·1
seated leaning forward	60·5 ± 12·1	71·5† ± 10·6	36·5* ± 8·2	47·4* ± 8·3
right lateral decubitus	53·5 ± 10·7	63·0 ± 9·8	30·2 ± 8·5	36·4 ± 8·1
left lateral decubitus	53·5 ± 10·7	62·0 ± 9·8	30·2 ± 8·5	36·4 ± 7·4
FEV_1 (% predicted)	28·2 ± 4·6	30·9 ± 9·8	20·2 ± 7·8	24·0 ± 7·9
Residual volume (% predicted)	232·9 ± 49·3	207·8 ± 45·3	264·8 ± 54·2	236·1 ± 60·7
Total lung capacity (% predicted)	127·8 ± 19·1	123·4 ± 14·9	135·3 ± 15·1	128·3 ± 12·8
Room air Pao_2 (mm Hg)	48·7 ± 7·2	51·8 ± 6·4	43·4 ± 5·8	48·5 ± 8·0
Room air $Paco_2$ (mm Hg)	49·3 ± 8·7	45·8 ± 4·3	56·3 ± 9·7	52·8 ± 6·5

*Significantly different from other postures: $p < 0.001$.
†Significantly different from other postures: $p < 0.05$.
Conversion: Traditional to SI units—Arterial oxygen (Pao_2) and carbon dioxide ($Paco_2$) tensions: 1 mm Hg = 0·133 kPa.

35 cm H_2O or less in the standing position, and a "moderate group" as those with a value greater than 35 cm H_2O. There were 23 and 17 patients in the severe and moderate categories. The severe group had a significantly ($p < 0.05$) lower FEV_1 than the moderate group (table 2), but the two groups did not differ significantly with respect to TLC, RV, or blood gases. Classification of patients into severe and moderate groups on the basis of the greatest Pi_{max} or percentage of predicted FEV_1, instead of Pi_{max} in the standing position, would have produced a similar distribution of patients and similar findings. The seated leaning-forward position was the preferred posture in 22 of the 23 patients in the severe group and 13 of the 17 patients in the moderate group, and was assumed automatically by these patients in an attempt to relieve their dyspnoea. The effectiveness of this posture as the optimum inspiratory pressure-generating position was confirmed—Pi_{max} being significantly greater ($p < 0.001$) on days 1 and 5 in the seated leaning-forward position than in the other positions in the "severe" group and greater ($p < 0.05$) on day 5 in the "moderate" group.

There was a significant increase in Pi_{max} from day 1 to day 5 in all postures, the p values being <0.005 for the moderate group and <0.01 for the severe group. Posture had no significant effect on the Pe_{max} generated in any of the six positions in either group of patients. There was, however, a significant improvement in Pe_{max} from day 1 to day 5 in both moderate and severe groups ($p < 0.01$). The mean values of Pe_{max} on days 1 and 5 were 120 ± 26 and 135 ± 27 cm H_2O in the moderate group and 73 ± 38 and 102 ± 26 cm H_2O in the severe group.

By linear regression analysis we related diminution in Pi_{max} to age ($r = 0.423$, $p < 0.05$), percentage deficit from ideal body weight ($r = 0.716$, $p < 0.001$), and residual volume expressed as percentage of predicted value ($r = 0.744$, $p < 0.001$) and by linear contrast analysis we related it to radiological signs of hyperinflation ($r = 0.414$, $p < 0.05$). The relationship betwen Pi_{max} and age simply reflects the normal decline with age.

The effect of posture on the sensation of dyspnoea by comparison with the sensation in the standing erect posture is presented in table 3. The superiority of the seated leaning-forward position over the other positions tested ($p < 0.001$) with regard to subjective relief of dyspnoea is striking.

Table 3 *Effect of posture on perceived dyspnoea (with the standing erect position as the reference posture) in patients with moderate and severe airflow limitation*

Posture	*% with dyspnoea*		
	relieved	*unchanged*	*exacerbated*
Supine			
Moderate	17·7	70·5	11·8
Severe	12·9	69·9	17·2
Seated erect			
Moderate	11·8	76·4	11·8
Severe	12·9	74·2	12·9
Seated leaning forward			
Moderate	82·6*	17·4	0
Severe	95·7*	4·3	0
Right lateral decubitus			
Moderate	17·7	76·4	5·9
Severe	12·9	78·5	8·6
Left lateral decubitus			
Moderate	17·7	76·4	5·9
Severe	12·9	78·5	8·6

*$p < 0.001$.

Table 4 *Effect of posture and treatment on physical signs (first figures are percentages of patients on day 1 and figures in parentheses percentages on day 5)*

Physical sign	*Standing*	*Seated*	*Seated leaning forward*	*Supine*	*Right lateral decubitus*	*Left lateral decubitus*
Costal paradox	70 (37·5)	60 (27·5)	42·5 (17·5)	65 (30)	65 (35)	65 (35)
Abdominal inspiratory inward movement	25 (10)	20 (7·5)	7·5 (0)	15 (2·5)	12·5 (2·5)	12·5 (2·5)
Inspiratory tracheal descent	87·5 (42·5)	87·5 (42·5)	87·5 (42·5)	87·5 (42·5)	87·5 (42·5)	87·5 (42·5)
Inspiratory sternomastoid contraction	92·5 (47·5)	92·5 (47·5)	82·5 (42·5)	92·5 (47·5)	92·0 (47·5)	92·5 (47·5)

The improvement in physical signs over the five days of hospital treatment and the reduction in the percentage of patients with these signs in the seated leaning-forward position are shown in table 4.

Discussion

Our normal values for Pi_{max} are strikingly similar to those from the two other large series reported,[3 13] in contrast to the lower values obtained in smaller series.[14 15] The normal values for Pe_{max} are similar to those of Black and Hyatt,[3] but considerably higher than the other reported values.[13–15] We can only surmise that these differences reflect minor variations in technique and selection of subjects, yielding differences in motivation, respiratory muscle strength, and skill in performing ventilatory manoeuvres. The absence of any postural effect on the maximal static pressures generated by our normal subjects is noteworthy.

The preference for the seated leaning-forward position in 22 of the 23 "severe" patients and 13 of the 17 "moderate" patients confirms previous reports.[2 16] This position was assumed automatically by these patients during acute exacerbations of their disease as the optimum position in which to obtain relief of dyspnoea. The superiority of this position as a generator of maximum inspiratory pressure (table 2) and its association with subjective relief of dyspnoea (table 3) is probably due at least in part to compression of abdominal contents and stretching of the diaphragm, thereby improving its length-tension relationship. Contrary to the findings of previous studies,[2 17] the supine position was infrequently the preferred posture in our patients (5%) and offered no advantage over the other postures as an inspiratory pressure generator or in subjective relief of dyspnoea. It would appear that improvement of diaphragm length-tension relationships is only one factor operating in the postural relief of dyspnoea in severe chronic airflow limitation.

The improvement in Pi_{max} over the five days in hospital (table 2) might be due to a sustained therapeutic concentration of theophylline or improvement in arterial blood gas tensions, or both. The reduction in lung volumes (TLC and RV) and improvement in FEV_1 from day 1 to day 5 were not significant. Nevertheless, even a modest reduction in residual volume (25% of predicted volume in the moderate group and 28% in the severe group) may have significantly decreased the mechanical disadvantage of the inspiratory muscles.

We have used Pe_{max} as an index of general debility because the expiratory muscles are not necessarily at a mechanical disadvantage in severe chronic airflow limitation. The importance of malnutrition in producing respiratory muscle weakness has recently been emphasised by Arora and Rochester[18] and our findings support this. The moderate and severe groups differed significantly ($p < 0{\cdot}05$) in percentage of ideal body weight, which averaged 91% ± 9% and 80% ± 7% in the moderate and severe groups respectively. In parallel with this difference in weight loss, the two groups differed significantly ($p < 0{\cdot}001$) in Pe_{max} (120 ± 26 and 73 ± 38 cm H_2O on day 1 in the moderate and severe groups respectively). This deficit in Pe_{max} in severe chronic airflow limitation has previously been described[12] and presumably reflects malnutrition and general debility. The relatively greater initial diminution in Pi_{max}—to mean values of 50% and 30% of predicted, compared with Pe_{max} values of 75% and 50% of predicted in the moderate and severe groups respectively—suggests that the mechanical disadvantage of the inspiratory muscles is an additional contributory factor acting in concert with malnutrition and general debility in the observed reduction in maximal static pressures.

We acknowledge the considerable degree ot interobserver variability in previous studies of physical signs in the respiratory system[19 20] and the consequent unsatisfactory nature of a one-observer approach to their detection. Despite this caveat, the postural dependence of costal paradox is interesting (table 4), and presumably reflects the enhanced pressure-generating efficiency of the inspiratory muscles in the seated leaning-forward position. All physical signs were significantly less on day 5 than on day 1, correlating with the improved inspiratory pressures and clinical state of the patients.

In conclusion, the seated leaning-forward position was assocated with the ability to generate higher maximum inspiratory pressures and with the greatest subjective relief of dyspnoea. Improvement in maximum static inspiratory pressures with treatment during the course of an acute exacerbation of chronic airflow limitation is paralleled by a reduction in abnormal physical signs.

Dr S O'Neill holds a Parker B Francis Foundation fellowship.

References

1 Rochester DF, Braun NMT, Arora NS. Respiratory muscle strength in chronic obstructive pulmonary disease. *Am Rev Respir Dis* 1979;**119**(2):151–4.

2 Sharp JT, Druz WS, Moisan T, Forster J, Machnach W. Postural relief of dyspnoea in severe chronic obstructive pulmonary disease. *Am Rev Respir Dis* 1980;**122**:201–11.

[3] Black LF, Hyatt RE. Maximal respiratory pressures: normal values and relationship to age and sex. *Am Rev Respir Dis* 1969;**99**:696–702.

[4] Crapo RO, Morris AH, Gardiner RM. Reference spirometric values using techniques and equipment that meets ATS recommendations. *Am Rev Respir Dis* 1981;**123**:659–64.

[5] Campbell EJM. Physical signs of diffuse airways obstruction and lung distension. *Thorax* 1969;**24**:1–3.

[6] Hoover CF. Diagnostic significance of inspiratory movements of costal margins. *Am J Med Sci* 1920;**159**:633–46.

[7] Cherniack RM, Raber MB, Normal standards for ventilatory function using an automated wedge spirometer. *Am Rev Respir Dis* 1972;**106**:38–46.

[8] Dubois AB, Botelho SY, Bedell GN, Marshal R, Comroe JH jun. A rapid plethysmographic method for measuring thoracic gas volume: a comparison with a nitrogen washout method for measuring functional residual capacity in normal subjects. *J Clin Invest* 1956;**35**:322–6.

[9] Halpern SL, Glenn MB, Goodhart RS. New height-weight tables: importance of new criteria. *JAMA* 1960;**173**:1576.

[10] Simon G. *Principles of chest x-ray diagnosis*. 4th ed. London: Butterworths, 1978:163–4.

[11] Armitage P. *Statistical methods in medical research*. Oxford: Blackwell Scientific Publications, 1971:203–5.

[12] Braun NMT, Rochester DF. Respiratory muscle strength in obstructive lung disease. *Am Rev Respir Dis* 1977:**115**(4):91.

[13] Gilbert R, Auchincloss JH jun, Bleb S. Measurement of maximum inspiratory pressure during routine spirometry. *Lung* 1978;**155**:23–32.

[14] Rinqvist T. The ventilatory capacity in healthy subjects: an analysis of causal factors with special reference to the respiratory forces. *Scand J Clin Lab Invest* 1966;**18**, suppl:88.

[15] Serisier DE, Mastaglia FL, Gibson GJ. Respiratory muscle function and ventilatory control: I—In patients with motor neurone disease. II—In patients with myotonic dystrophy. *Q J Med* 1982;**51**:205–6.

[16] Barach AL. Chronic obstructive lung disease: postural relief of dyspnoea. *Arch Phys Med Rehab* 1974;**55**:494–504.

[17] Barach AL, Beck GJ. Ventilatory effects of head-down position in pulmonary emphysema. *Am J Med* 1954;**16**:55–60.

[18] Arora NS, Rochester DF. Respiratory muscle strength and maximal voluntary ventilation in undernourished patients. *Am Rev Respir Dis* 1982;**126**:5–8.

[19] Smyllie HC, Blendis LM, Armitage P. Observer disagreement in physical signs of the respiratory system. *Lancet* 1965;ii:412–3.

[20] Godfrey S, Edwards RHT, Campbell EJM, Newton-Howes J. Clinical and physiological association of some physical signs observed in patients with chronic airways obstruction. *Thorax* 1970;**25**:285–7.