An analysis of pre-operative Pao$_2$ in a general surgical population

M. L. DIAMENT AND K. N. V. PALMER

From the Department of Medicine, University of Aberdeen

Two hundred and thirty one patients awaiting elective surgery were divided on the basis of spirometric examination into normal (group A) and those with increased airway resistance (group B). The mean arterial oxygen tension for the 151 normal subjects was 96·3 ($\pm$11·6) mm. Hg. There was a significant inverse correlation of Pao$_2$ with age and dynamic lung volumes. The 80 patients in group B were significantly older and their mean Pao$_2$ was 88·7 ($\pm$12·9) mm. Hg. There was, however, no correlation between Pao$_2$ and age in this group, probably because the increased airway resistance had a greater influence in lowering the arterial oxygen tension than did the age factor alone.

The increasing use of the oxygen electrode in clinical practice has awakened interest in the normal arterial oxygen tension (Pao$_2$). This is authoritatively stated to be 100 mm. Hg (Roughton, 1964) but, until the normal range is known, the interpretation of the significance of single values under clinical conditions is uncertain. This is especially important in the post-operative patient, as the development of hypoxaemia can be expected in all patients after abdominal operations (Diament and Palmer, 1966). There are, however, few published reports of the Pao$_2$ in patients awaiting surgery. Conway, Payne, and Tomlin (1965) found a mean Pao$_2$ of 91·8 ($\pm$8·7) mm. Hg for a group of 70 pre-operative patients who were clinically free of cardio-respiratory disease. We have measured the blood-gas tensions and carried out spirometric measurements on a group of patients who were undergoing elective abdominal surgery. None of these patients had any clinical evidence of cardio-respiratory disease and all were considered fit for major surgical procedures. However, subclinical respiratory impairment is often present in these patients (Diament and Palmer, 1967). Therefore, on the basis of spirometry, they were divided into two groups—group A in whom the forced expiratory volume in one second expressed as a percentage of the forced vital capacity (F.E.V.$_1$%) was greater than 70 and who were considered, therefore, not to have increased airways resistance, and group B in whom the F.E.V.$_1$% was less than 70 and who were considered to have some obstruction to air flow. In both groups, an analysis was made to determine how the Pao$_2$ varied with age, sex, height, weight, smoking habits, the dynamic lung volumes and the arterial carbon dioxide tension (Paco$_2$).

PATIENTS AND METHODS

The number of men and women in the groups, their mean ages in years ($\pm$S.D.), heights (in.), weights (lb.), and number of cigarettes smoked daily are shown in Table I.

TABLE I
MEAN VALUES FOR AGE, HEIGHT, WEIGHT, AND SMOKING HABITS IN THE TWO GROUPS

Measurement			Group A	Group B	P
			Men		
No.			65	57	
Age (years) ..			43·4$\pm$16·8	60·3$\pm$9·9	<0·001
Height (in.) ..			68·0$\pm$2·3	67·5$\pm$2·9	N.S.
Weight (lb.) ..			154·9$\pm$18·3	143·5$\pm$25·6	N.S.
Cigarettes/day ..			9·1$\pm$10·0	9·5$\pm$9·5	N.S.
			Women		
No.			86	23	
Age (years) ..			45·1$\pm$15·9	56·8$\pm$15·9	<0·005
Height (in.) ..			62·9$\pm$2·4	62·7$\pm$2·8	N.S.
Weight (lb.) ..			130·3$\pm$21·7	127·7$\pm$19·1	N.S.
Cigarettes/day ..			5·4$\pm$7·6	7·3$\pm$8·5	N.S.

All the patients were interviewed soon after admission to the Aberdeen Royal Infirmary, when their agreement to take part in the study was obtained. The study was carried out when the patients were fully ambulant.

An arterial blood sample was obtained from the brachial artery into a heparin-lubricated syringe with the patient semi-recumbent. The patient was encouraged to relax and to breathe naturally, and

the blood was allowed to fill the syringe under its own pressure. The sample was immediately immersed in a mixture of ice and water in a vacuum flask and the blood-gas tensions were measured *in triplicate* as soon as possible afterwards, using electrodes[1] which were calibrated between each sample according to the manufacturer's instructions. The standard deviation for a single measurement for the oxygen electrode was 1·7 mm. Hg and for the carbon dioxide electrode 1·2 mm. Hg.

A forced expiratory spirogram was recorded using the Vitalograph, also with the patient semi-recumbent, and the forced vital capacity (F.V.C.) and forced expiratory volume in 1 second (F.E.V.₁) were calculated. At least three curves were recorded, the best being used for the calculation. Spirometric measurements were recorded at A.T.P.S. (ambient temperature and pressure, saturated).

RESULTS

The mean values ($\pm$S.D.) for the blood-gas tensions and spirometric measurements are shown in Table II for the two groups.

The mean Pao₂ for men in group A was 96·1 ($\pm$10·9) mm. Hg and for women 96·5 ($\pm$12·1) mm. Hg. In group B, the mean Pao₂ for men was 90·1 ($\pm$12·5) mm. Hg and 85·3 ($\pm$13·7) mm. Hg for women. Both these mean values were significantly different from those in group A, but the mean Pao₂ was not significantly different between men and women in either group.

The mean Paco₂ for men in group A was 40·9 ($\pm$3·6) mm. Hg and for women 39·0 ($\pm$3·8) mm. Hg, and this difference was significant (P<0·01). In group B, the mean Paco₂ for men was 40·7 ($\pm$4·3) mm. Hg and for women 40·5 ($\pm$4·1) mm. Hg, which was not a significant difference.

[1]Manufactured by Radiometer, Copenhagen

TABLE II
MEAN VALUES FOR Pao₂, Paco₂, F.E.V.₁ AND F.V.C. IN THE TWO GROUPS

Measurement	Group A	Group B	P
Men			
Pao₂ (mm. Hg)	96·1±10·9	90·1±12·5	<0·01
Paco₂ (mm. Hg) ..	40·9± 3·6	4·07±4·3	N.S.
F.E.V.₁ (l., A.T.P.S.)	3·54±0·79	2·31±0·71	<0·001
F.V.C. (l., A.T.P.S.)	4·49±0·94	3·75±0·97	<0·001
Women			
Pao₂ (mm. Hg) ..	96·5±12·1	85·3±13·7	<0·001
Paco₂ (mm. Hg) ..	39·0±3·8	40·5±4·1	N.S.
F.E.V.₁ (l., A.T.P.S.)	2·36±0·61	1·40±0·55	<0·001
F.V.C. (l., A.T.P.S.)	2·96±0·68	2·21±0·82	<0·001

The mean spirometric measurements were within $\pm$10% of the predicted normal values for men and women in group A. In group B, as might be expected, all the spirometric measurements were significantly lower than those in group A (P<0·001) for men and women.

In Table III, correlation coefficients are given for Pao₂ against the other variables for men and women in both groups, and regression equations are given where the correlation is a statistically significant one. In group A, for men and women, Pao₂ correlated with age, F.E.V.₁, and F.V.C. In group B, Pao₂ correlated with F.E.V.₁ and F.V.C. in men only. The Pao₂ did not correlate with height, weight or smoking habit in any of the groups. There was no correlation between Pao₂ and Paco₂ except in women of group A.

DISCUSSION

In this study there are two groups of patients who, on the basis of spirometric measurements, were divided into those who did not (group A) and those who did (group B) have evidence of increased airway resistance. Group B were older than group A.

TABLE III
CORRELATION COEFFICIENTS AND REGRESSION EQUATIONS

Pao₂ v.	Men		Women	
	Group A	Group B	Group A	Group B
Age	−0·476 (P<0·001) Pao₂=109·5−0·31 (Age)	−0·062 (N.S.)	−0·532 (P<0·001) Pao₂=114·8−0·41 (Age)	−0·282 (N.S.)
F.E.V.₁..	+0·467 (P<0·001) Pao₂=73·2+6·46 (F.E.V.₁)	+0·377 (P<0·01) Pao₂=74·7+6·65 (F.E.V.₁)	+0·371 (P<0·001) Pao₂=79·0+7·41 (F.E.V.₁)	+0·293 (N.S.)
F.V.C.	+0·419 (P<0·001) Pao₂=74·1+4·88 (F.V.C.)	+0·371 (P<0 01) Pao₂=72·1+4·80 (F.V.C.)	+0·315 (P<0 01) Pao₂=79·8+5·62 (F.V.C.)	+0·386 (N.S.)
Paco₂	+0·082 (N.S.)	−0·233 (N.S.)	−0·262 (P<0·05) Pao₂=129·5−0·85 (Paco₂)	−0·104 (N.S.)
Height	+0·074 (N.S.)	+0·134 (N.S.)	−0·171 (N.S.)	+0·261 (N.S.)
Weight	−0·352 (N.S.)	+0·114 (N.S.)	−0·187 (N.S.)	+0·220 (N.S.)
Cigarettes/day	+0·157 (N.S.)	−0·044 (N.S.)	+0·091 (N.S.)	+0·188 (N.S.)

The mean Pao$_2$ for the normal group, men and women combined, was 96·3 ($\pm$11·6) mm. Hg. This is somewhat higher than that reported by Mellemgaard (1966), who found the mean Pao$_2$ of 80 normal subjects to be 93·1 ($\pm$8·0) mm. Hg.

The mean Pao$_2$ of the group B subjects was 88·7 ($\pm$12·9) mm. Hg. The difference between these means, 7·6 mm. Hg, is significant (P<0·001). Raine and Bishop (1963) found the mean Pao$_2$ of subjects less than 40 years was 95·3 ($\pm$6·9) mm. Hg, but for those above 40 years it was 88·2 ($\pm$9·8) mm. Hg. The mean age of our normal group was 44·3 years, whereas it was 58·6 years in group B, which suggests that age is an important factor in determining the lower mean Pao$_2$ of this group. In the normal group the Pao$_2$ was found in fact to correlate with age, which indicates that the Pao$_2$ becomes less as age advances.

The regression equation we obtained for Pao$_2$ against age for normal men was similar to that obtained by others for males and females combined (Raine and Bishop, 1963; Mellemgaard, 1966). The equation we obtained for normal women differed from that for men in that it showed a steeper slope and indicated that the Pao$_2$ falls more rapidly with age in women than in men. Although this fall is not significantly different from that of the men, young women have a somewhat higher Pao$_2$ level than young men, which we think is most likely due to hyperventilation. This is supported by our finding of a significantly lower Paco$_2$ level in women.

In normal subjects there is a statistically significant correlation between Pao$_2$ and the dynamic lung volumes in both sexes. The consistency of these correlations indicates that the Pao$_2$ is a sensitive indicator of ventilatory function, and that the Pao$_2$ can be expected to be reduced whenever ventilatory function is impaired, whether the impairment is obstructive or restrictive in nature.

The Pao$_2$ depends on the tension of oxygen in the alveoli (Pao$_2$), whether there is any barrier to diffusion of oxygen through the alveolar-capillary membrane and into the red cells, and on the degree of venous admixture or shunt effect from blood coming from areas of lung which are poorly ventilated although adequately perfused. In addition, blood from bronchial, pleural, and thebesian veins contributes to the venous admixture effect. The Pao$_2$ depends on the inspired oxygen tension, the alveolar carbon dioxide tension (Paco$_2$) and the respiratory exchange ratio.

With advancing age, lung volumes diminish, there is a fall in compliance, the diffusing capacity diminishes (Cohn, Carroll, Amstrong, Shepard, and Riley, 1954), and there is an increase in the alveolar-arterial tension difference and in the physiological dead-space/tidal volume ratios (Raine and Bishop, 1963; Mellemgaard, 1966). Impaired diffusion becomes important at rest only when the Pao$_2$ is much reduced, and as this value does not diminish with age, it is apparent that the fall in Pao$_2$ with age is due to the increased inequalities of ventilation/perfusion ratios in the lungs of older subjects. This is supported by the absence of a significant correlation in normal men between Paco$_2$ and age (r= $-0\cdot17$), indicating that overall alveolar hypoventilation does not contribute to the falling Pao$_2$ with increasing age in them. In women, on the other hand, there is a significant correlation between Paco$_2$ and age (r= $+0\cdot24$; P<0·05), indicating that alveolar hypoventilation may contribute to the fall in Pao$_2$ with age in them, and this added factor may well be the reason why the Pao$_2$ declines more rapidly with age in women than in men. This might be thought to be associated with increased weight in older women, but the Paco$_2$ did not correlate significantly with weight in any of the four groups.

It is perhaps surprising that in neither men nor women was smoking (number of cigarettes per day) significantly correlated with any of the blood-gas tensions or spirometric measurements in either group. Nor was there a significant difference between the normal and abnormal groups in the number of cigarettes smoked per day. These findings may reflect the number of non-smokers in this series and the number of relatively light smokers.

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