

# Use of an ear oximeter to assess lung function

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**Al-Dulymi, R. and Hainsworth, R. (1975).** *Thorax*, 30, 566–568. Use of an ear oximeter to assess lung function. Values of arterial oxygen saturation were estimated using an ear oximeter while subjects breathed a mixture of 15% oxygen in nitrogen. Results obtained from patients with lung disease were clearly separated from results obtained from normal subjects, and the lowering of saturation was related to the clinical severity of the disease. Patients with low oximeter readings with 15% oxygen also had low levels of arterial oxygen tension during exercise.

Probably the most accurate method for assessing overall lung function is to determine the arterial blood gas tensions during exercise. However, this method is time consuming, involves arterial catheterization, and requires equipment for blood gas analysis. We have developed a simple method for assessing lung function by reducing the oxygen content of the inspired air and measuring the effect on haemoglobin saturation using an ear oximeter.

## METHODS

There were 21 normal subjects, male and female aged 16–68, with no history of pulmonary or cardiac disease and 52 patients undergoing routine pulmonary function studies. The diagnoses were chronic airways obstruction (33), asbestosis (4), sarcoidosis (3), fibrosing alveolitis (3), and pneumoconiosis (1). Eight patients were found to have no abnormality of lung function as assessed by standard tests (lung volumes, expiratory flow rates, and blood gas tensions during exercise). The

clinical diagnoses in these patients were bird fancier's disease' (4), sarcoidosis (2), silicosis (1), and 'breathlessness' (1). The blood gases and pH and forced expired volume/forced vital capacity ratios in these groups are listed in the Table.

A vasodilator cream was rubbed on the upper part of the subjects' ears and the subjects were seated in a comfortable high-backed chair with a V-shaped head support to which the oximeter ear piece was clamped. The oximeter (Atlas Universal, type E45B) was set up by adjusting one point on the scale when the subject breathed 100% oxygen and another set point when the ear was made ischaemic by compressing it between the light source and the detector. Used in this way arterial haemoglobin saturations could be predicted from a regression line with an accuracy of  $\pm 2.9\%$  (2 standard deviations) for haemoglobin saturations above 65%.

A gas mixture containing 15% oxygen in nitrogen was transferred from a cylinder to a 120 l spirometer which was always well flushed out with

TABLE

BLOOD GASES, pH, AND FEV<sub>1</sub>/FVC RATIOS IN THE THREE GROUPS OF PATIENTS: MEANS  $\pm$  SD AT REST AND ON EXERCISE

	Chronic Airways Obstruction (33)		Other Lung Disease (11)		'Normal Patients' (8)	
	Rest	Exercise	Rest	Exercise	Rest	Exercise
Pao <sub>2</sub> (mmHg)	76.9 $\pm 13.1$	65.0 $\pm 14.1$	79.4 $\pm 11.7$	59.9 $\pm 14.1$	97.5 $\pm 8.7$	95.9 $\pm 5.3$
Paco <sub>2</sub> (mmHg)	38.4 $\pm 4.7$	42.4 $\pm 7.7$	37.8 $\pm 3.3$	40.0 $\pm 5.8$	37.5 $\pm 3.7$	38.0 $\pm 2.0$
pHa	7.39 $\pm 0.07$	7.37 $\pm 0.05$	7.41 $\pm 0.04$	7.38 $\pm 0.05$	7.42 $\pm 0.03$	7.41 $\pm 0.05$
FEV <sub>1</sub> /FVC %	57 $\pm 5.6$		81 $\pm 8.0$		81 $\pm 5.0$	

gas before being filled. The subjects were fitted with nose clips and, using a two-way Douglas valve, breathed in from the spirometer and out into the room. Readings were first taken from the oximeter while the patient was breathing room air and again after breathing 15% oxygen in nitrogen for 4–5 minutes.

All the patients underwent a standard exercise test. They stepped on and off a 30 cm step 20–30 times per minute. Arterial blood was withdrawn through a brachial artery catheter during the fifth minute of exercise and analysed for oxygen tension with an oxygen electrode (Electronic Instruments Ltd).

### RESULTS

**HAEMOGLOBIN SATURATION (USING EAR OXIMETER) WHEN BREATHING ROOM AIR AND 15% OXYGEN IN NITROGEN** In the normal subjects the average estimated haemoglobin saturation when breathing room air and 15% oxygen were 96.6% (SD  $\pm 0.90$ ; range 94–97) and 93.1% (SD  $\pm 1.62$ ; range 88–96) respectively.

In the eight patients with normal results from conventional lung function tests ('normal patients') the estimated saturations with room air and 15% oxygen were 93.8% (SD  $\pm 3.54$ ; range 88–98) and 88.2% (SD  $\pm 1.34$ ; range 86–90).

The estimated haemoglobin saturation in all other patients when breathing room air (range 68%–96%) was significantly different from both the normal groups ( $P < 0.001$ ). However, there was considerable overlap of individual results. On the other hand, the values obtained in patients breathing 15% oxygen (range 58%–88%) showed no overlap at all with the control group and only one overlap with the 'normal patients' group.

**COMPARISON OF RESULTS OF OXIMETER TEST WITH RESULTS OF EXERCISE TEST** The results of estimated oxygen saturation when breathing 15% oxygen have been plotted against the results, in the same subjects, of the arterial blood oxygen tensions breathing room air during the fifth minute of exercise (Figure). There is a highly significant correlation between these results ( $r = 0.80$ ,  $P < 0.001$ ). The points have been divided into nine rectangles by drawing lines through the points corresponding to 86% and 76% saturation and 80 mmHg and 65 mmHg tensions. The points in the upper right rectangle were within normal limits by both tests. The points in the middle rectangle were moderately abnormal and those in the lower left rectangle severely abnormal by both

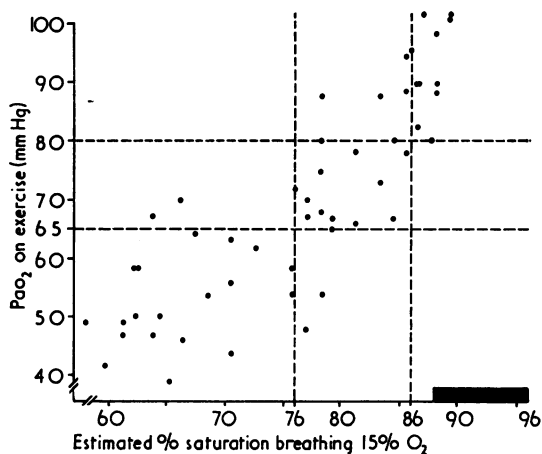


FIGURE Comparison of oxygen tension of blood taken during fifth minute of exercise with haemoglobin saturation on breathing 15% oxygen. Saturations estimated using ear oximeter and regression equation. Range 88–96% saturation obtained in control subjects (no arterial tensions). Horizontal and vertical interrupted lines are arbitrary limits of moderately severe and severe results.

tests. Four patients were moderately abnormal by the oximeter test and normal by the exercise test and four were moderately abnormal by one test and severely abnormal by the other. However, no patients were normal by one test and severely abnormal by the other. There was good agreement in 44 out of 52 patients and no failure of the oximeter test to predict patients who had low oxygen tensions on exercise. The eight patients in whom there was not good agreement reflect the statistical scatter of the results; four had bronchitis and four had other diseases associated with hypoxaemia.

### DISCUSSION

The sensitivity of this test of lung function is achieved because of the shape of the oxygen dissociation curve for haemoglobin. Because the top part of the curve is flat, measurements of saturation when breathing room air are much less sensitive as an indicator of impaired lung function than are measurements of oxygen tension. However, when the subject breathes 15% oxygen, if alveolar  $CO_2$  tension remains normal, alveolar oxygen tension should drop to about 70 mmHg. If the difference between alveolar and arterial oxygen tensions is less than 10 mmHg, arterial oxygen tension would be greater than 60 mmHg and haemoglobin saturation would be

greater than 90%. Below 60 mmHg the dissociation curve becomes steeper and saturation falls more sharply. Arterial oxygen tension would fall below 60 mmHg if the alveolar to arterial difference in oxygen tension was abnormally large or if the carbon dioxide tension was abnormally high. We measured  $P_{aCO_2}$  in 25 patients breathing 15% oxygen and found no significant change from the values obtained during air breathing (values were 38.4 mmHg, SD  $\pm$ 4.9 and 38.8 mmHg, SD  $\pm$ 4.4 breathing 15%  $O_2$  and air respectively).

In order to be useful the test of lung function must clearly separate the results from patients with lung diseases from those from normal subjects. There should be no patients with normal results, there should be no normal subjects with abnormal results, and the results of the test should correlate with the severity of the disease. The results of the estimated saturation during 15% oxygen breathing satisfy these criteria. The results correlated well with the results of the standard exercise test. The results of the oximeter test never failed to detect patients with lung disease. There were no normal subjects with saturation below 88% and there were no patients with any of the lung diseases studied who had a saturation greater than 88%. It is interesting to note that the eight patients who were found to have no abnormality to routine tests of lung function did have a significantly lower saturation on breathing 15% oxygen than the control group.

It is possible, therefore, that our test is more sensitive to minor disorders than the conventional tests.

Our test of rebreathing 15% oxygen has advantages over a rebreathing method described by Lal, Gebbie, and Campbell (1966) because the inspired oxygen mixture is accurately known in our method. This means that normal values can be predicted accurately and there is less risk of severe hypoxia than when the alveolar oxygen is continuously falling.

Ear oximetry combined with breathing slightly hypoxic mixtures has been shown to be of value in detecting impaired lung function. While it is not suggested that it can replace arterial blood gas analyses for the accurate assessment of lung function, oximetry is easy, safe, and, because it is non-invasive, readily repeatable. Ear oximetry used in this way could have a useful rôle in the assessment of lung function, both as a screening test and in follow-up studies.

#### REFERENCE

- Lal, S., Gebbie, T., and Campbell, E. J. M. (1966) Simple method for improving the value of oximetry in the study of pulmonary oxygen uptake. *Thorax*, **21**, 50.

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