OXYGEN ADMINISTRATION BY VENTIMASK IN PATIENTS WITH RESPIRATORY FAILURE

By Poh Soo Chuan+, M.B., M.R.C.P. Ed., D.T.C.D.

Patients with chronic obstructive pulmonary disease in respiratory failure from acute chest infections present a special problem with regard to the relief of hypoxia. Oxygen therapy to correct the hypoxaemia becomes necessary but may sometimes lead to depression of ventilation and the development of carbon dioxide narcosis and acidaemia. Various attempts to overcome this therapeutic problem of the relief of hypoxia without producing a dangerous rise in the arterial carbon dioxide tension ($PaCO_2$) have been made, and include oxygen by nasal catheter at low flow rates (Barach 1938, Cherniak 1967), oxygen by tent with intermittent brief periods of breathing air (Donald 1953, Cohn 1954), and the continuous administration of an oxygen mixture controlled with an accuracy of 1-5% in the range of 24 to 35% oxygen (Campbell 1960, Hutchison 1964). Recently Campbell and Gebbie (1966) devised simple plastic disposable masks (Ventimask*) based on the Venturi principle which allow fixed concentrations of 24, 28 and 35% oxygen to be given, at the same time avoiding rebreathing by the high air flow entering the mask.

This paper reports the effects of these masks on arterial oxygen tension (PaO_2) in patients with chronic respiratory failure over a period of several hours. Attention was also paid to the changes in the $PaCO_2$ and in the arterial pH.

METHODS

Ten patients with chronic obstructive pulmonary disease and various degrees of hypoxaemia and hypercapnia were studied. All the patients were clinically in a stable condition and no other forms of therapy were given except oral bronchodilators and expectorants. Eight of the patients were opium addicts of many years duration and had taken their daily "dose" of opium about two hours before the initial blood sample was taken. An indwelling Cournand needle was placed in the brachial artery from which blood was sampled in heparinised syringes anaerobically, and analysed immediately for PaO_2 with the use of Radiometer pO_2 electrode E 5046. Blood pH and pCO_2 readings were obtained from the Siggaard-Andersen nomogram via the Astrup method using the Radiometer Type AME 1 microequipment.

The baseline blood sample was taken after the needle had been in situ for 30 minutes. Oxygen was then given via the 24% mask for 1 hour, at the end of which, the 28% mask was used for another 45 minutes. This was then replaced by the 35% mask for another 1 hour. Blood samples were drawn every half hour whilst the patient was on continuous oxygen therapy during the study. Gas sampled during inspiration from within the masks was analysed on the Scholander analyser and was found to agree within 1% of that stated by the manufacturer.

RESULTS

The blood gas and pH values are presented in Table I. All the patients had moderate degrees of hypoxaemia and hypercapnia whilst breathing room air at rest. The changes in the individual blood gas tension whilst on oxygen therapy are shown in Fig. 1.

It is seen, from Fig. 1, that with the 24% mask, the PaO_2 values were generally about the same at the half and one hour period, and showed an average rise of 13 mm. Hg. (range 8-21 mm. Hg.) from air breathing levels. In addition, all the patients attained a PaO_2 of more than 50 mm. Hg.

The PaO_2 rose an average of a further 13 mm. Hg. when the 28% mask was used. During this whole period of 1½ hours there was no significant change in the $PaCO_2$ and pH values.

With the 35% mask, the average value of the PaO_2 was 98 mm. Hg., representing an 82% rise over baseline airbreathing levels. The $PaCO_2$ rose an average of 3 mm. Hg. from the baseline level with the highest rise of 7 mm. Hg. in Case 2. The pH did not fall by more than 0.05 units. In general, the pH and blood gas values at the ½ hour period did not differ greatly from those at the 1 hour period.

+ Tan Tock Seng Hospital, Singapore.

* Manufactured by Oxygenaire Ltd., Basingstoke, Hampshire, England.

TABLE I

READINGS FOR THE 24% AND 35% ARE THE AVERAGE OF THE ½ AND 1 HOUR SAMPLES

Case	Air			24% O_2		28% O_2		35% O_2		
	PaO_2	$PaCO_2$	pH	PaO_2	$PaCO_2$	PaO_2	$PaCO_2$	PaO_2	$PaCO_2$	pH
1	42	68	7.33	63	66	72	66	92	71	7.30
2	48	69	7.39	61	70	74	70	91	76	7.34
3	46	67	7.34	58	66	70	66	73	62	7.35
4	64	50	7.41	74	52	86	54	101	56	7.37
5	50	59	7.35	60	62	76	64	86	63	7.32
6	46	53	7.37	59	52	72	51	87	56	7.34
7	63	58	7.35	71	56	87	59	111	60	7.32
8	58	69	7.36	68	67	85	70	110	72	7.32
9	72	55	7.39	90	56	108	61	136	59	7.34
10	49	63	7.35	66	63	72	62	91	67	7.32
Mean	54	61	7.36	67	61	80	62	98	64	7.33

DISCUSSION

Depression of ventilation during acute episodes of chest infection in patients with chronic obstructive pulmonary disease has been attributed to increased mechanical work of respiration with resulting failure of the respiratory muscles or to poor function of the lungs themselves together with abnormal response of the respiratory centre. In such circumstances hypoxia, which has been shown to be a factor responsible for the resulting acute pulmonary hypertension (Enson 1964, Stuart-Harris 1968), acts as a stimulus to respiration, and its relief towards a normal level by a rise in the concentration of inspired oxygen is fraught with the danger of producing further hypoventilation and carbon dioxide narcosis.

Mental changes following oxygen therapy were first reported by Barach (Barach 1938), who suggested that oxygen administration to patients with emphysema should be given cautiously via nasal catheters, initially with low concentration with increase of oxygen flow at daily intervals (Barach 1950). In an attempt to prevent progressive carbon dioxide retention, oxygen administration by tent with intermittent brief periods of air breathing was suggested. (Donald 1953, Cohn 1954). However, objections to the intermittent method have been raised (Campbell 1960, Cullen 1967), and the method has even been described "as akin to bringing a drowning man to the surface of the water, occasionally" (Campbell 1965). Campbell (Campbell 1960), elaborating Barach's original concept showed that adequate relief of hypoxaemia in these patients can safely be provided by small increases in the inspired oxygen concentration and recommended greater precision in oxygen dosage to bring them out of the zone of hypoxaemia associated with evidence of tissue dysfunction and damage ($PaO_2 < 30$ mm. Hg.). A higher level in the arterial oxygen tension was also desirable so as to guard against any deterioration in the respiratory or circulatory systems and to relieve the strain of the various responses to hypoxia. At the same time it is recognised that

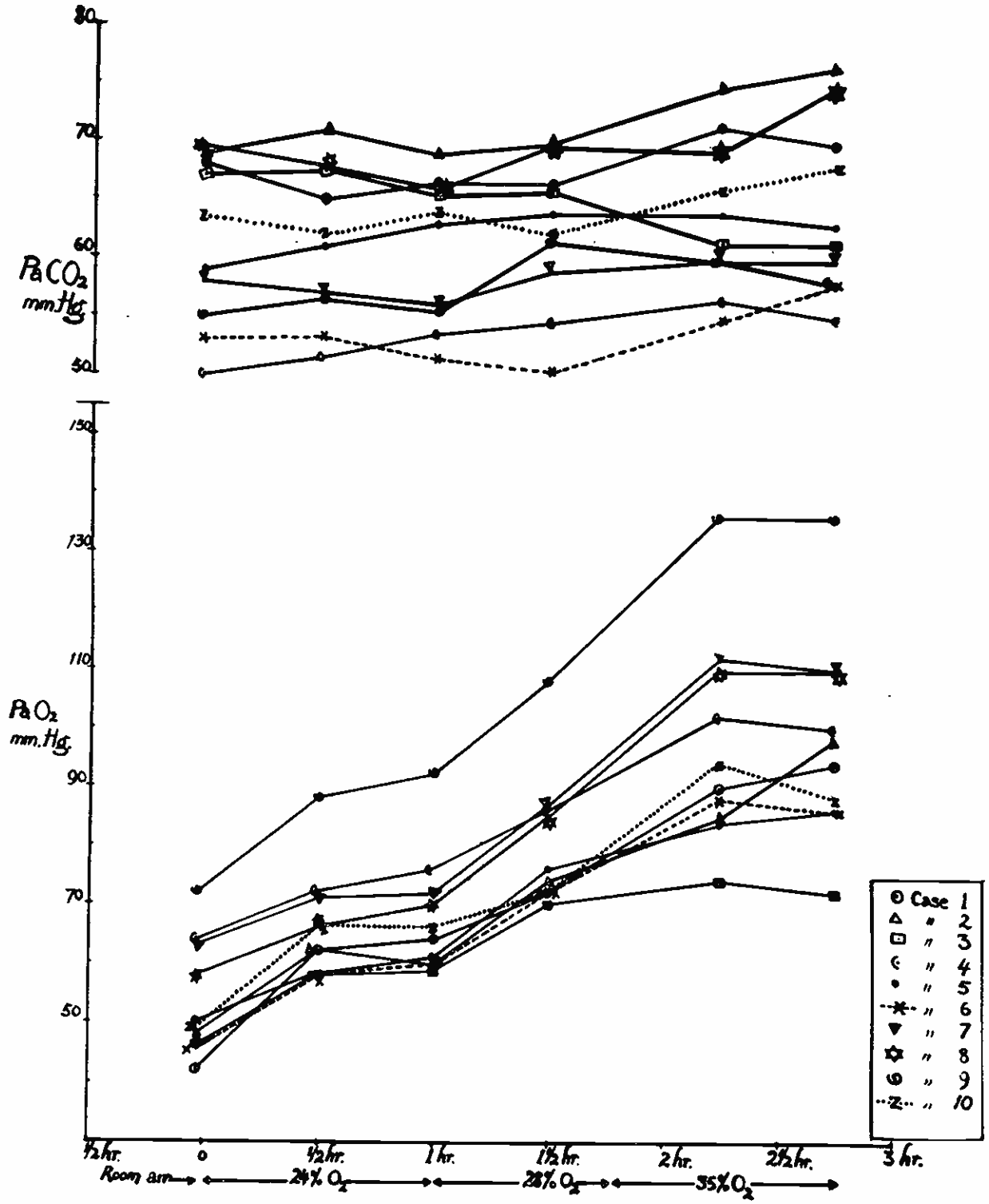

Fig. 1.

the danger of inducing carbon-dioxide narcosis is greater in those with already a high $PaCO_2$ (Hutchison 1964) as well as the fact that the risk is also greater the greater the hypoxaemia (Campbell 1967).

To allow for more precise control of the rise of the PaO_2, controlled therapy by masks (Ventimasks) based on the Venturi principle were introduced (Campbell 1966). The Ventimask, using the high air-flow with oxygen enrichment principle, allows a fixed concentration to be given, irrespective of the patient's minute ventilation, and has been shown to be technically superior to several other devices (Bethune 1967).

The minimal safe goal of oxygen therapy can be accepted as the achievement of a PaO_2 of 50 mm. Hg. (Hutchison 1964). The results here show that by gradually increasing the inspired oxygen concentration it has been possible to provide adequate oxygenation without an undue rise in

the $PaCO_2$ in these patients. The highest rise in the $PaCO_2$ was 7 mm. Hg. in Case 2 and this can hardly be regarded as narcotic. This rise in hypercapnia may result from diminished work of respiration as a result of relief of hypoxia or due to a worsening of the ventilation perfusion ratio distribution in the lungs due to changes in the pulmonary circulation (Pain 1965). In addition the patients who were opium addicts and had just taken a dose of opium, which one might expect to depress the respiratory centre, fared just as well as those who were non addicts. The results are in general agreement with those reported recently (Schiff 1967). These patients were all, as stated, in a stable condition clinically. However, patients with chronic obstructive lung disease, in acute respiratory failure may fail to achieve adequate oxygenation, as shown by Mithoefer *et al* (1967), who found that with the 24% mask, 70% of his patients failed to attain a PaO_2 of 50 mm. Hg. and questioned the advisability of the use of the mask unless PaO_2 can be measured.

Patients with acute or chronic respiratory failure due to chronic obstructive lung disease often show critical hypercapnia as a result of having received uncontrolled administration of oxygen (McNicol 1965, Lal 1965). It is hoped that with more cautious oxygen administration, as offered by the Ventimask, from the beginning, the need for intubation or tracheostomy for these patients will decrease. However, there is still the need to determine frequently the arterial PO_2, PCO_2 and pH during therapy.

SUMMARY

The effect of oxygen administration by Ventimasks on the blood gas and pH values was studied in ten patients with chronic respiratory failure. With the 24% mask, all the patients achieved a PaO_2 above 50 mm. Hg. The average PaO_2 rise was 13 mm. Hg., whilst the 35% mask resulted in another 31 mm. Hg. rise. Throughout the study the $PaCO_2$ rose on an average of 3 mm. Hg., the highest rise recorded being 7 mm. Hg. pH did not fall by more than 0.05 units.

The results show that the Ventimask provides a satisfactory method of controlled oxygen therapy. It has been possible to obtain a gradual rise in the PaO_2 of these patients without any serious deterioration of alveolar ventilation.

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