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A New Oxygen Applicator for Simultaneous Mouth and Nose Breathing*

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We have developed a new O_2 applicator to try to overcome the problems of long-term oxygen therapy that ensures a sufficient oxygen supply for both nasal and oral breathing and prevents mucosal irritation. Placed on the upper lip, it is unobtrusive. The principle is as follows: due to an enlarged outlet area, turbulence occurs and the oxygen is reduced. Thus, an oxygen cloud is formed that can be inhaled by both mouth or nose. The efficiency of our O_2 applicator was compared with a face mask in six healthy subjects and patients with COPD. A similar increase in Po_2 was found up to an oxygen flow of 2 L/min for nasal and oral breathing. Mild hypercapnia resulted in three patients with COPD only when a face mask was used and only when patients breathed through the nose. All patients preferred the new applicator. ***(Chest 1993; 103:1157-60)***

Long-term oxygen therapy is a well-established form of therapy for pulmonary diseases, especially for cor pulmonale.[1] As has been demonstrated in several studies, the more hours a day oxygen is administered, the more life expectancy is prolonged.[2,3] The various means of providing oxygen currently in use are less than ideal. Usually masks of various kinds and single- or double-lumen nasal cannula with or without a conservation device are used and in special cases the transtracheal route is used.[4] In the methods of oxygen delivery using cannula, these maintain close contact with the mucous membrane, which, together with the dry oxygen flow, leads to local irritation and occasionally to infection and bleeding.[4-6] A rare complication is air embolism.[7] The cannulas frequently become displaced so that the patient may receive no oxygen enrichment at all.

Mouth breathing causes a further, often underestimated problem since the oxygen is no longer inhaled.[8-10] This occurs while speaking, during vigorous exercise, and frequently when asleep because at least half of patients with COPD and related conditions snore with their mouths open.[11]

The oxygen mask alone ensures supplementation of the inspiratory air with oxygen for both mouth and nose breathing. However, standard oxygen masks are uncomfortable, cause warm air congestion, hinder speech, and a simultaneous food intake is inhibited unless a Venturi mask is used. The dead space is increased, which can result in a rise in Pco_2 in patients with borderline hypoventilation.[5,12]

To try to overcome these problems, we have developed an O_2 applicator (Oxynasor, PARI, Starnberg, Germany) that can be used for both mouth and nose breathing without being cumbersome and that ensures sufficient oxygen without irritating the respiratory mucosa. This report describes the principle of this new device and compares its efficiency with that of an oxygen mask, since an oxygen mask allows a constant oxygen administration for both mouth and nose breathing.

Methods

Principle of the New Applicator

The principle of the new applicator is depicted in Figure 1. Enlargement of the outlet area and additional turbulence as a result of centrifugal flow reduces the high initial oxygen flow velocity from the thin tube. Thus, oxygen accumulates around the applicator in the form of a cloud and can be inhaled by mouth or nose.

The oxygen flow velocity at the outlet is calculated as the oxygen flow is divided by the diameter of the tube through which the oxygen flows. For example, for nasal oxygen therapy at 2 L/min and the usual 3-mm interior diameter of the tube, the velocity at the outlet is 3.3 m/s. The outlet area of the new device is approximately 20 times larger; therefore, the velocity at the outlet is reduced by the same factor of 20 to approximately 16 cm/s.

Depicted in Figure 2, 2 L/min of cigarette smoke, used to make the air stream visible, flow through a double-lumen nasal cannula. The high initial velocity of the air stream at the outlet is reduced after about 5 to 6 cm due to turbulence, which demonstrates, that a high local concentration of oxygen should be achieved at the nasal mucosal surface.

A prototype of the new device reduced the oxygen flow markedly due to the enlarged outlet area and the centrifugal turbulence of the oxygen stream (Fig 3). Rapid cloud formation occurs when smoke is used to illustrate the effect.

This oxygen cloud can be inhaled in the direction of the nose or of the mouth even by a low inspiratory flow while breathing through the mouth as shown in Figure 4.

When an oxygen mask is used, the airstream always decelerates due to the distance between the oxygen outlet and the mouth or nose (Fig 5).

Comparative Clinical Studies

After approval by the hospital ethics committee and obtaining informed consent, the O_2 applicator (Oxynasor) was compared with an oxygen mask (Salter Labs, Arvin, Calif, Fig 5) in 12 subjects, 6 healthy individuals and 6 patients suffering from COPD of different levels of severity (Table 1). Thus, a broad range of blood gas values

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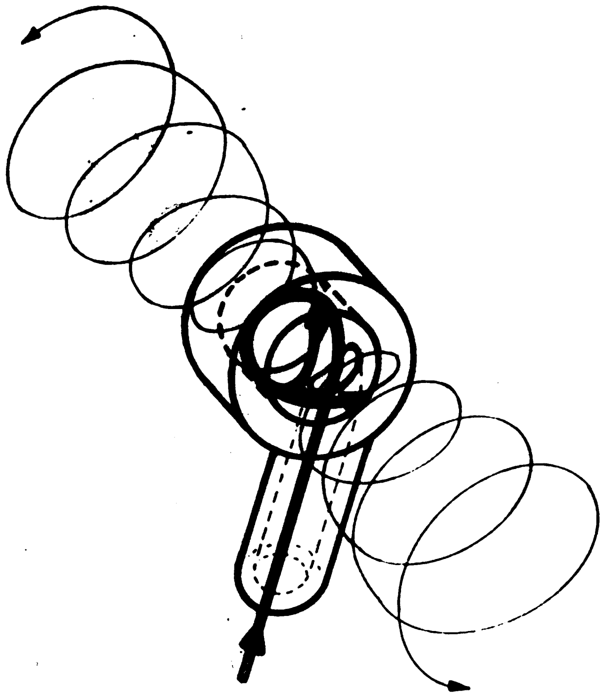

FIGURE 1. Principle of the new oxygen applicator. The hight velocity of oxygen at the cannula outlet is markedly decelerated owing to turbulence and the enlarged outlet area.

was obtained.

Oxygen was applied on the same day in randomized order via the O_2 applicator or oxygen mask from an oxygen cylinder with humidifier. An oxygen flow of 0 to 4 L/min was applied in five separate studies (0, 1, 2, 3, and 4 L/min). Each study consisted of 10 min of mouth breathing and 10 min of nose breathing. Mouth or nose breathing, at a given oxygen flow, was carried out in randomized order. An arterialized capillary blood sample from a hyperemic ear lobe was analyzed by a blood gas analyzer (type 738, AVL, D-6380 Bad Homburg) at the end of each 10-min O_2 administration.

Statistical evaluation was performed using Student's *t* distribution for means (two-tailed probability).

RESULTS

The initial blood gas values during room air breathing (oxygen flow = 0 L) were not significantly different for the oxygen mask and the new applicator, whether subjects breathed through the mouth or nose (Table 1).

The average percentage increase in Po_2 was not significantly different for oxygen administration up to 2 L/min for the two methods of administration, neither for oral nor for nasal breathing (Fig 6). Significance was achieved at 3 L/min (mouth breathing, $p = 0.06$; nose breathing, $p = 0.05$). The differences in Po_2 were highly significant at 4 L/min ($p < 0.001$) for both devices. A percentage increase in Po_2 was demonstrated in all 12 patients. The SDs were similar with

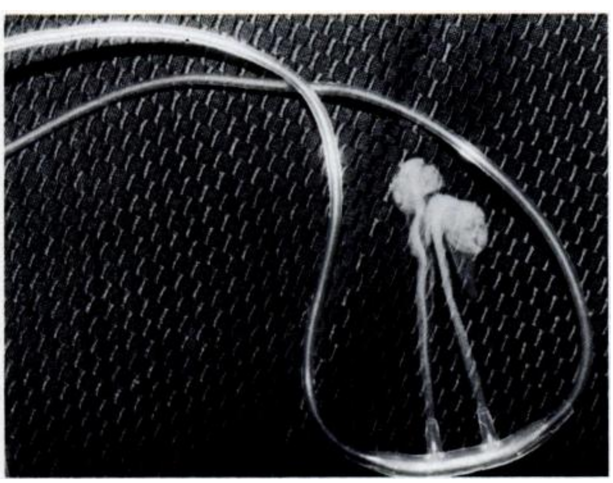

FIGURE 2. The high velocity of gas at nasal cannula outlet, made visible by cigarette smoke (flow, 2 L/min).

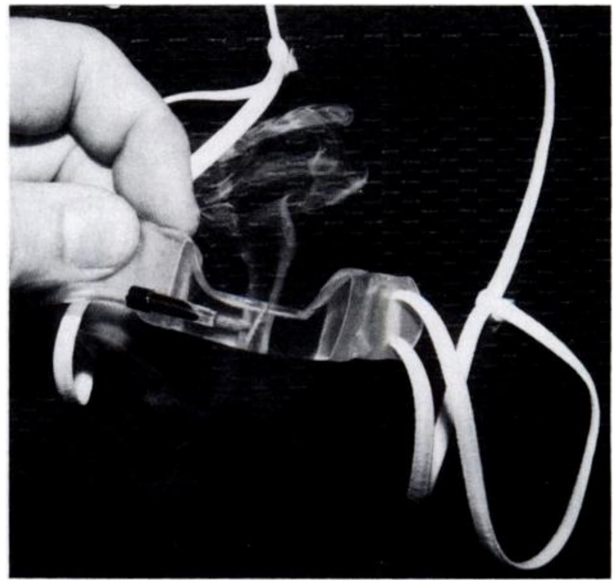

FIGURE 3. Prototype of the new probe, depicting the decelerated gas due to turbulence formation, made visible by cigarette smoke (flow, 2 L/min).

FIGURE 4. Oxygen flow at the outlet made visible by cigarette smoke (flow, 2 L/min). Nearly all the smoke is inhaled by mouth breathing.

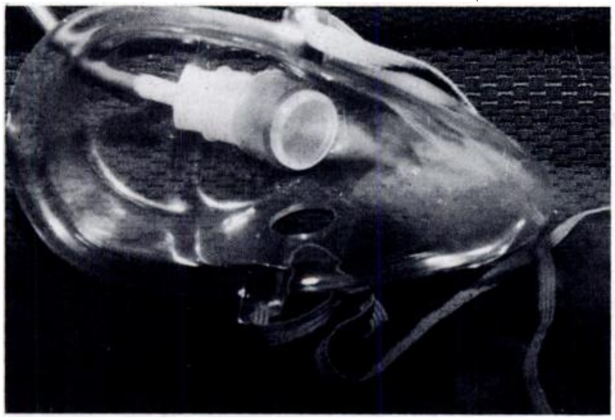

FIGURE 5. Oxygen flow inside a face mask, made visible by cigarette smoke.

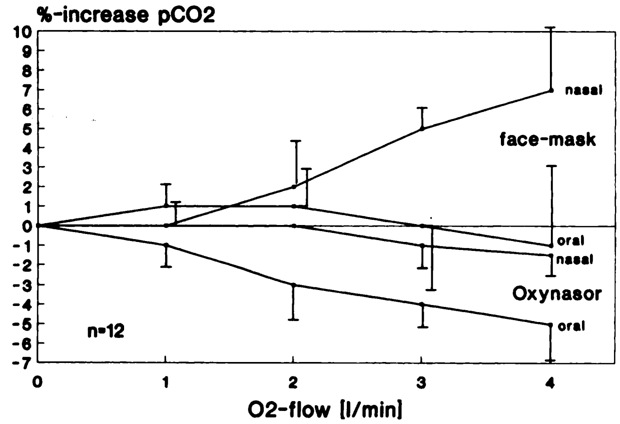

FIGURE 7. Change in the carbon dioxide partial pressure in arterial blood in percent in relation to the basal values for different oxygen flows for oral and nasal breathing over a 10-min period. Mean and SD for both applicators.

both methods of O_2 administration.

The Pco_2 increased in the range of 7 percent when 4 L of oxygen per minute were given by oxygen mask while nose breathing (Fig 7), and became abnormal (over 45 mm Hg) in three cases. Mouth breathing resulted in slight hyperventilation during oxygen breathing, which prevented hypercapnia to a greater extent using the O_2 applicator compared with the face mask.

All 12 subjects preferred the O_2 applicator to the face mask because it was more comfortable and much less obtrusive. However, the study time was rather short.

DISCUSSION

A comfortable oxygen delivery system is desirable for long-term oxygen therapy. Face masks are hardly ever used in Germany as they are uncomfortable (warm air congestion, speech impaired, and food uptake impossible) and can cause a rise in Pco_2.[5,12] In Great Britain, North America, and Scandinavia more comfortable, cooler Venturi masks providing controlled oxygen are widely used, although they are obtrusive and are difficult to use while eating. Single- or double-lumened nasal cannulas are frequently used.[5,12] These, like O_2 masks, easily become displaced, especially at night, and may cause nasal mucosal irritation, dehydration, crusting, and bleeding. There has even been a report of air embolism.[7] These adverse effects are due not only to mechanical irritation, but also to the high oxygen velocity, in the range of 3 to 5 m/s, for the cannulas when used at the oxygen flow of 2 L/min (Fig 2). These adverse effects do not occur when a face mask is used, as the high oxygen velocity present on entering the mask is much lower by the time the nasal or oral mucosa is reached (Fig 5).

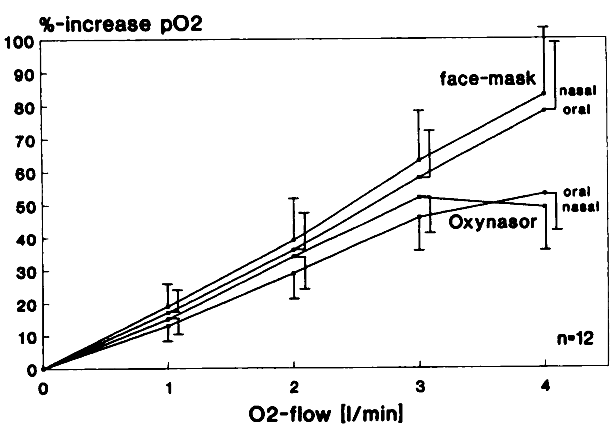

FIGURE 6. Increase in the oxygen partial pressure in arterial blood in percent, in relation to the basal values for different oxygen flows for oral and nasal breathing over a 10-min period. Mean and basal SD for both applicators.

The O_2 applicator (Oxynasor) greatly reduces the high velocity at the orifice by means of centrifugal turbulence, allowing a low linear velocity of oxygen, similar to a cloud (Fig 3). In this manner, oxygen can be sucked up either by oral or nasal breathing (Fig 4). Because of the flow characteristics, slight differences in inspiratory negative pressures suffice.

A significant difference is not documented for oxygen application up to 2 L/min by face mask or by the O_2 applicator (Fig 6); however, the entire oxygen stream can no longer be inhaled when over 3 L of oxygen per minute are applied via the new applicator, as the oxygen velocity is too rapid. For 4 L/min, approximately 50 percent of the oxygen administered is lost as it flows rapidly past the mouth and nose.

Since over 95 percent of the patients require less than 3 L of oxygen per minute at rest in long-term home O_2 therapy,[1,2,6] the new applicator may be suitable for the majority of patients and is advantageous because of the lack of mucosal irritation. The oxygen supply via the new applicator is more reliable than via nasal cannulas, as this application form functions well for both mouth and nose breathing. This may be of great importance, as many of the

Table 1—*Blood Gas Values*

	Normal Subjects		Chronic Obstructive Pulmonary Disease	
	(Mean ± SD)	(Extremes)	(Mean ± SD)	(Extremes)
No.	6		6	
Age, y	58 ± 6.8	(23-66)	60 ± 4.1	(51-75)
FEV_1, % pred	97 ± 4.3	(85-107)	57 ± 17.1	(30-78)
Face mask				
Oral breathing				
Po_2, mm Hg	77.0 ± 8.1	(64-86)	57.5 ± 5.0	(50-62)
Pco_2, mm Hg	36.8 ± 2.0	(35-40)	37.3 ± 4.4	(33-44)
Nasal breathing				
Po_2, mm Hg	76.7 ± 8.2	(65-85)	57.7 ± 5.2	(50-64)
Pco_2, mm Hg	36.7 ± 2.1	(34-40)	37.0 ± 4.3	(33-43)
O_2 applicator (Oxynasor)				
Oral breathing				
Po_2, mm Hg	77.3 ± 7.8	(65-86)	56.8 ± 4.8	(50-62)
Pco_2, mm Hg	37.0 ± 2.3	(34-40)	37.2 ± 4.6	(33-44)
Nasal breathing				
Po_2, mm Hg	77.4 ± 7.7	(65-85)	58.1 ± 4.3	(65-85)
Pco_2, mm Hg	36.9 ± 2.1	(34-39)	37.3 ± 4.2	(34-44)

patients undergoing long-term oxygen therapy snore through the mouth.

In this study of short duration, all 12 participants favored the new applicator to the oxygen mask.

An additional advantage of the new applicator is that no rise in Pco_2 occurs for both nose and mouth breathing, in contrast to the nonventuri face mask (Fig 7). Patients tend to hyperventilate when mouth breathing O_2 with both applicators.

In conclusion, the new oxygen applicator (Oxynasor) is well-suited for oral and nasal oxygen application up to a flow of approximately 3 L/min and provides a similar improvement in PaO_2 by either route. The device is fairly unobtrusive compared with O_2 masks and may allow the patients to eat, talk, and sleep without the reduction in PaO_2 that frequently occurs when nasal O_2 is administered. Further studies are presently being carried with regard to nocturnal oxygen delivery and oxygen administration during exercise via the new applicator.

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