Patient–oxygen dissociation curves: surveying the spectrum of oxygen-delivery methods

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ABSTRACT

Objective: To describe the spectrum of oxygen-delivery methods.

Design: Clinical audit.

Setting: Medical wards of a tertiary referral teaching hospital in August 2004.

Participants: 98 medical patients receiving supplemental oxygen.

Results: Of the 98 patients, 40 were not receiving oxygen by customary methods. In classifying the patterns of oxygen delivery, we describe the transcephalic, submental, and (inadvertent) rectal approaches, as well as lachrymal insufflation and the "Venturi cravat". We also describe novel oxygen-weaning methods, including the half-wean, reverse wean, and placebo wean.

Conclusions: Many patients receive oxygen by unconventional methods. We postulate that this is evidence of a renewed interest in the historical routes of oxygen delivery.

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Early attempts to understand the role of oxygen date back to Hippocrates (460–370 BC), who knew that inspired air contained something that entered the heart and spread through the body. Aristotle (384–322 BC) showed that experimental animals would not survive in airtight boxes. Leonardo da Vinci (1452–1519) described how air entered the lungs by the bellows action of the chest wall.

Despite the crucial role of oxygen in maintaining human life, it was not until the 18th century that it was used as a therapy. In 1774, Priestley was the first to produce oxygen by heating red oxide of mercury in a glass vessel over metallic mercury. He showed that this gas supported life in mice and caused a candle to burn more vigorously. He called this "dephlogisticated air". However, it was his friend, Antoine Laurent Lavoisier (1743–1794) who coined the term "oxygène", derived from the Greek meaning "acid producer". The discovery of oxygen led to the establishment in 1799 of the Pneumatic Institute in England for the treatment of diseases by inhalation of oxygen. The announcement in the *Bristol Gazette* called for

> . . . the attendance of persons in Consumption, Asthma, Palsy, Dropsy, obstinate Venereal Complaints, Scrophula or King's Evil, and other diseases, which ordinary means have failed to remove . . .

However, the early use of oxygen as treatment was not limited to inhalation. In 1886, Brins Oxygen Co in London (now BOC) started to produce oxygen commercially. They advertised oxygen for intravenous administration, and also promoted the benefits of administering oxygen through the skin and subcutaneous tissues, and via the stomach, rectum, vagina and uterus.[1] Oxygen enemas were used to treat liver and intestinal diseases,[2] and subcutaneous oxygen was used to resuscitate asphyxiated infants in the early 20th century.[3] In the 1960s and '70s, the use of hyperbaric oxygen for wound healing became popular, and, in fact, is supported by some scientific data.[4]

> The Lord God formed man out of the dust of the ground and He breathed into his nostrils the breath of life
>
> Genesis 2: 7

However, the major use of supplemental oxygen is by inhalation in the treatment of hypoxia. The nasal catheter was popularised by the Scottish surgeon Sir William Arbuthnot Lane in 1904, and positive-pressure intermittent oxygen therapy was used in 1944 by the American physician Alvan L Barach.[5] Many lives were saved by the medicinal use of oxygen in World War II.

From these beginnings, our understanding of cardiopulmonary physiology has improved tremendously, and supplemental oxygen is now used routinely. Nevertheless, simple things are often the hardest to achieve, and numerous audits have shown that, even in the current era, oxygen may not be used appropriately. For example, in one study of 66 patients in India,[6] no gas was flowing from the cylinder in 35% of cases, while, in another 35%, it was at a lower rate than specified; none of the patients were receiving oxygen as prescribed.

We aimed to survey how oxygen was delivered to patients on the medical wards of a tertiary teaching hospital in Australia.

METHODS

Over a period of a week in August 2004, a clinical audit was undertaken of five medical wards in a tertiary referral teaching hospital to ascertain:

- the number of patients receiving oxygen;
- the amount of oxygen they were receiving; and
- whether there were any problems with oxygen delivery.

Two investigators performed the audit using a previously formatted data-collection sheet. Patients' medical notes were not audited.

RESULTS

Overall, 98 of 150 patients were using oxygen at some time, via nasal prongs or a

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facemask. About 40% of patients (40/98) needing oxygen were not receiving it in the customary manner.

From this audit, and our previous clinical experience, we have classified eight major patterns of unorthodox oxygen delivery.

The transcephalic approach: The facemask is perched on the patient's head, over the frontal lobes. This may be particularly helpful for dementia or stroke, or when treating any cerebral hypoxia. It may also be a useful means of oxygen delivery when the patient is eating.

The transbuccal approach: The nasal prongs are placed over the patient's cheeks to allow percutaneous absorption.

Lachrymal insufflation: The nasal prongs are placed over the bridge of the nose with one prong pointed at each epicanthus. The continuity between the tear ducts and the nasal passages provides good anatomical support for this method of oxygen delivery.

The submental approach: The nasal prongs are applied just below the chin. This method is contraindicated in those with excess subcutaneous tissue or "bull" necks.

The Venturi cravat: The facemask is placed over the larynx, below the chin. This method has the advantage of doubling as a fashion accessory, and Venturi nibs could be colour coordinated to match the patient's outfit.

Per rectal: This appears to be an inadvertent method resulting from the patient sitting on the nasal prongs.

Jet-prong ventilation: The nasal prongs are properly in place, but the oxygen flow is set to the maximum that the dial allows: up to 12 L/min. This method is recognised by the whistling that is audible from down the hall, the windblown appearance of the patient, and the nostrils flapping in the breeze.

Nebulotherapy: This occurs when a nebuliser is left on, with the patient nowhere in sight. The medication is vented to the room, as with an aromatherapy diffuser.

Five other patterns observed appeared to be forms of oxygen weaning:

The half-wean: The patient has only one nasal prong in place, with the other prong venting beside the nostril.

The reverse wean: The prongs are reversed so that even though they are placed appropriately, they are angled away from the patient's nostrils; this is usually accompanied by the "lasso" placement of the prongs around the patient's head. We believe that this may be a form of respiratory muscle training, in that the prongs entrain air away from the nostrils, increasing the work of breathing. This method should not be used for prolonged periods.

The placebo wean: The nasal prongs or facemask are in place appropriately, but the proximal end is not connected to the oxygen outflow valve. This method may be particularly useful for those who have developed a psychological dependence on oxygen.

Oxygen-at-a-distance and its variations: This set of methods involves physical separation between the oxygen prongs or facemask and the patient. For example, in the audit we found instances in which the patient was sitting in a chair, while the nasal prongs were on the bed, carefully aimed in the patient's general direction. Variations of this distance-delivery method of weaning included oxygen on the floor, oxygen hanging on the wall, oxygen on the bedside table, or oxygen emerging from behind the pillow.

Oxygen in absentia: This is the extreme end of the patient–oxygen dissociation curve, and occurs when the oxygen is left on, and the patient is in the radiology department having x-rays.

DISCUSSION

Our findings that only 60% of patients receive oxygen appropriately conform with those of previous studies. In a 12-month study in Saudi Arabia, arterial oxygen tension was excessive in 55%, suboptimal in 5%, and adequate in only 40% of patients.[7] A Scottish study found that 21 of 119 patients (18%) were using oxygen masks incorrectly,[8] and a Canadian study found that oxygen therapy was neither prescribed nor administered as carefully as antibiotics.[9] The latter study reported that the flow meter was off in 34% of patients, and in 26% of patients oxygen was administered without medical orders.

Our most notable finding was the resurgence of alternative and complementary modes of oxygen delivery. For example, there seems to be renewed interest in the percutaneous and rectal modes of delivery, and some innovative approaches to weaning. This is likely to be a fertile area for future research; for example, does oxygen diffuse across down pillows at the same rate as across those made of polyester? To what extent is rectal delivery affected by the presence of underwear? Do high rates of ambient oxygen lead to better ward outcomes?

Although poor oxygen delivery is likely to be a financial drain on hospital resources, one benefit may be to improve air quality in hospitals. There is some evidence that modern hospitals suffer from "sick building syndrome", in which recycled air leaves personnel feeling unwell.[10] A randomised controlled trial of "nebulotherapy" may therefore be timely.

In this era of high-tech equipment, it is ironic that use of simple nasal prongs or facemasks poses such a challenge. It echoes a comment by Samuel Wallian from 1885:[11]

> . . . the most serious draw back or hindrance to the rapid progress of the so-called oxygen treatment lies in the fact that, with our present facilities, or lack of facilities, its extensive clinical exhibition involves more time, care and cumbersome apparatus than a majority of practitioners can devote to it.

Do Samuel Wallian's words still apply over a century later?

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