Continuous positive airway pressure in low income countries

Continuous positive airway pressure (CPAP) is a form of therapy used for the treatment of a wide variety of conditions causing respiratory distress in patients of all ages. It entails the provision of a continuous supply of a mixture of compressed air and oxygen delivered in varying proportions, and at flow rates and pressures according to the patient's requirements. While it is readily achievable in modern, well equipped hospitals, this life saving treatment is frequently unavailable in remote hospitals in poor countries because of the expense and logistical problems involved in the provision of medical oxygen and air. An alternative method of providing CPAP which overcomes these disadvantages is described.

The Diamedica Baby CPAP apparatus

The Diamedica Baby CPAP apparatus (Fig 1) is designed to enable CPAP to be delivered safely and economically from a single unit in circumstances in which more conventional facilities are unavailable or unaffordable. It incorporates a standard oxygen concentrator which has been modified to produce an increased output with a variable concentration of oxygen. The concentrator has twin flow meters for air and oxygen, each with a maximum flow rate of 8.l/min^{-1}.

Figure 1

The oxygen/air mixture then passes over a water humidifier and via lightweight respiratory tubing to silicon nasal prongs or a face mask. The concentrator has been further modified so that warm waste air from the concentrator's compressor is directed towards the humidifier bottle. This increases the temperature of the inspired gases raising the dew point of the water thus providing enhanced humidification to the device. Laboratory tests were carried out to determine these effects.

Pressure is maintained throughout the respiratory cycle by directing the gas flow to a container of water at the distal end of the circuit via a tube with an open end at an adjustable depth beneath the surface. The pressure is determined using a calibrated dial which enables the depth of the tube to be adjusted in situ. As the pressure control is distal to the patient interface the system provides accurate control of the pressure with minimal pressure variation at the patient interface

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Discussion

The administration of CPAP to infants and young children requires equipment capable of delivering the following:

1. A total gas flow exceeding the patient's maximum inspiratory flow rate. This is to ensure that the pressure in the airway remains above atmospheric pressure throughout the respiratory cycle. It also prevents dilution of the inspired mixture with atmospheric air, enabling the maximum possible FiO_2 to be administered when required.
2. A FiO_2 that can be adjusted according to the needs of the patient at different stages of treatment.
3. A means of adjusting the airway pressure.
4. An inspired mixture which can be warmed and humidified to approximately ambient temperature and above 90% relative humidity.

When administered in well equipped hospitals having reliable monitoring equipment and centralised supplies of oxygen and compressed air, CPAP treatment is simple, effective and inexpensive.

For many hospitals in poor countries the situation is very different. Oxygen and compressed air are generally supplied in cylinders which may require transportation over long distances on roads which may, at times, be impassable. In these circumstances the supply may be interrupted. Even when cylinders are available the flow requirements for CPAP are so great that the expense involved may make the treatment unaffordable. Oxygen concentrators have been used for many years as an inexpensive source of oxygen in low income countries both for oxygen therapy [1,2], and during anaesthesia and the postoperative period [3,4]. They have been particularly useful in maintaining the supply in remote locations where delivery of cylinders may be subject to frequent interruptions.

Figure 2

Oxygen / Air Mixing Chart

Oxygen Flowmeter \ Air Flowmeter (lt/min)	0	1	2	3	4	5	6	7	8
1	95.0	57.5	45.0	38.8	35.0	32.5	30.7	29.4	28.3
2	95.0	70.0	57.5	50.0	45.0	41.4	38.8	36.7	35.0
3	95.0	76.3	65.0	57.5	52.1	48.1	45.0	42.5	40.5
4	95.0	80.0	70.0	62.9	57.5	53.3	50.0	47.3	45.0
5	95.0	82.5	73.6	66.9	61.7	57.5	54.1	51.3	48.8
6	95.0	84.3	76.3	70.0	65.0	60.9	57.5	54.6	52.1
7	95.0	85.6	78.3	72.5	67.7	63.8	60.4	57.5	55.0
8	95.0	86.7	80.0	74.5	70.0	66.2	62.9	60.0	57.5

% Oxygen

Assuming an oxygen concentrator output of 95% Oxygen

A recent study [5] compared the performance of seven concentrators under the extreme conditions encountered in a range of developing countries. The AirSep Elite oxygen concentrator was ranked the highest according to its overall performance and a concentrator from this manufacturer was selected for use in the Diamedica CPAP apparatus.

High concentrations of oxygen, when administered to infants over prolonged periods, can have a detrimental effect on the retina and may lead to blindness. For this reason the percentage of oxygen being delivered at any time is kept under constant review and is restricted to the minimum effective level. In the absence of an oxygen analyser the inspired oxygen concentration is displayed on an accompanying chart located on the device (Fig 2).

Airway pressures between 3-6cm H_2O are commonly used but in severe cases pressures up to 10 cmH_2O may be required. High levels may impede venous return and diminish cardiac output so the minimal effective level is applied and adjustments made according to the patient's response.

Even when cylinders of oxygen and compressed air are available, and can be supplied in sufficient quantities, the cost of providing high flow rates over prolonged periods may be unaffordable in low income countries. The cost of cylinders of compressed air and oxygen varies from country to country and even from place to place according to the geography. However a standard E-size cylinder of oxygen (680 litres) in most African hospitals is in the region of £5 and the cost of compressed air is approximately the same.

The provision of CPAP in paediatric patients requires high flows of both compressed air and oxygen and a total flow of 10 l/min^{-1} would therefore not be unusual. At this rate a single cylinder would last approximately 1 hour giving a total cost exceeding £100 for 24 hours. In contrast the same flows can be supplied by the oxygen concentrator at a cost of £0.10 per hour or £2.40 for 24 hours.

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Note

The AAGBI does not endorse or recommend any particular manufacturer or device.