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Low Cost CPAP for the Developing World

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ABSTRACT

Nasal CPAP is a proven modality for respiratory distress of neonates and infants. The problem for resource poor countries is that its apparatus is expensive. We have successfully employed small 'fish tank pumps' to generate gas flow sufficient to generate bubble CPAP. Oxygen can be entrained as necessary. The pumps draw on room air at ambient humidity, thus avoiding 'dry' air from usual sources. The limbs of tubing can be run through water baths to increase the temperature of inspired gas if desired. In 21 infants suffering from bronchiolitis or pneumonia, with average weight of 2.9 kgs, the apparatus produced a mean increase in SpO2 levels of 13.05%, decrease in RR of 20.2 breaths per minute and decrease in HR 18.36 per min. There were no complications of the apparatus. One infant, however, succumbed to systemic effects of sepsis. The system provides relatively inexpensive CPAP for resource poor countries. Costs could be further reduced by bulk buying.

Introduction

The application of Continuous Positive Airway Pressure (CPAP) to the spontaneously breathing infants is a recognised therapeutic intervention for respiratory distress of the newborn, as well as bronchiolitis and pneumonia in the infant. It has been shown to be safe and to reduce the need for mechanical ventilation [1]. It may be applied through intranasal prongs or a nasal mask, with pressure generated by an upstream mechanical ventilator, or by downstream immersion of an exiting tube under required depths of water (Figure 1). In either case, the gases are usually supplied from bottled containers and, therefore, the mixture is likely to be dry and cold. Inhalation of 'dry' gas reduces the flow of mucous in the airways by interfering with the function of cilia and by drying secretions [2]. Inflammation may follow, with reduction of lung capacity, compliance and oxygenation [3]. In adults, such interference with flow of secretions has been demonstrated within 10 minutes of application [4]. Inhalation of cold gas has long been known to reduce muco-ciliary action [5]. Within the airways, Inhaled gas is heated and humidified to equilibrium with surrounding tissue, but this process takes energy. Dawson et al suggest that 1-2% of the infant's energy consumption on the first day of life could, per hour, be expended on cold and dry gas [6].

Furthermore, they emphasise that oxygen consumption increases with the temperature gradient between child and environment. Inhaled gases can be heated and humidified before application but the apparatus is expensive. For example, in Australian dollars the single-use unit which humidifies the inhaled gas costs around $120 but its permanent heating base costs around $3600. To these costs are added those of single-use nasal prongs ($24) and gas supply. A standard 10 L tank costs around $260. If gas flows at 6 L/min, it will be emptied by 6 hours costing about $12 per day (Figure 1). Though the cost of refilling would appear to be minimal, third world budgets are limited, and gas re-supply often not guaranteed. Therefore, the use of small pumps that can entrain air at room temperature and humidity and deliver it at a rate to generate sufficient CPAP may be of advantage in developing world hospitals. The basic gas would be room air and the CPAP, by itself,

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may increase oxygenation to desired levels (Figure 2). If added oxygen is needed, it can be entrained into the inspiratory side of the apparatus, at the level of the nasal prongs, or further back in the tubing. If desired, inspired gas can be warmed by immersing tubing in warmed water bathes before it enters the nares. Pressure within the tubing, and thus CPAP, would be generated by the 'fish tank pump', supplemented by hydrostatic pressure associated with the depth of immersion of the exiting tubing beneath water in a nearby container.

Figure 1: CPAP.

Figure 2: High Flow.

To reduce the loss of pressure at the nostrils though any gap surrounding the nasal prongs, the size of the gap was reduced by inserting the prongs through appropriately sized holes cut into non-damaging adhesive tape which was applied across the nostrils. In Bangladesh, we aimed to examine the usefulness of small pumps otherwise designed for aquaria, fitted with plastic tubing acquired from hardware shops, at a total cost of at a total cost of $26. CPAP was applied to noses with standard a Hudson Nasal Prong cannula, costing $24 each. Ethical approval was given by governance of Shishu Children's Hospital, Mymensingh Community Hospital and Joyramkura Hospitals, Bangladesh. Parental approval was secured for each application of the apparatus.

Method

We employed Hailea ACO 6604 Air pumps with twin outlets each delivering approx. 4.5L/min, for a total of 9L/min. The prongs were applied through holes cut in underlying Duoderm to minimise escape of gas from the nares . The apparatus was held in place in front of the face by Velcro attachment to a knitted cap or a Canberra Hat (Figure 1). The exiting tube was submersed below water in a cheap container with depth measured by an affixed tape. Progress was monitored by recordings of Oxygen Saturations levels (SpO2), Heart Rate (HR) and Respiratory Rate (RR).

Results

21 infants with respiratory distress associated with bronchiolitis and pneumonia were recruited (Figure 3). The average weight was 2.900 Kg. Before the application of 'fish tank CPAP', respiratory support had comprised the application of supplemental oxygen via small bore nasal tubes. Overall, with CPAP between 6-7 cm/ H2O, there was a mean increase in SpO2 levels of 16.76%, a mean decrease in RR of 21.2 breaths per minute and a mean decrease in HR 17.52 per min (Table 1). The average time on CPAP was 16.76 hours. Reduction of RR was noted within several hours by some. No complications were noted. One child, however, succumbed to overwhelming sepsis.

Figure 3: CPAP in use in Mymensingh Children's Ward.

Table 1: Neonate and Infant data collected from 3 Bangladeshi Hospitals.

Reason	Age	Weight	PEEP	Time on	Oxygen	1st RR	Last RR	1st SpO_2	Last SpO_2	1st HR	Last HR	Comments
Bronchiolitis*	5 months	2200	7	12hrs	Yes	70	56	80%	97%	155	148	
Bronchiolitis*	3 months	2800	7	7hrs	Yes	80	63	78%	96%	160	156	
Respiratory Distress*	3 months	2700	6	13hrs	Yes	76	50	85%	98%	150	138	
Bronchiolitis*	5 days	2400	7	7hrs	Yes	78	56	87%	98%	160	142	
Bronchiolitis*	6months	2700	6	5hrs	Yes	68	57	87%	97%	126	122	
Bronchiolitis*	2 months	2400	6	6hrs	Yes	76	60	88%	98%	196	136	
Bronchiolitis*	24 months	2800	6	3hrs	Yes	68	62	87%	95%	126	124	Tx stopped pt irritable
Bronchiolitis*	18 months	2900	6	5hrs	Yes	79	56	88%	96%	136	130	
Bronchiolitis*	12 months	2900	7	14hrs	Yes	76	62	80%	97%	160	144	
Bronchiolitis*	6 months	2700	6	9hrs	Yes	70	60	84%	97%	121	120	
Bronchiolitis*	2 months	2400	6	7hrs	Yes	76	60	88%	98%	140	130	
Bronchiolitis*	6 months	2700	6	9hrs	Yes	70	60	84%	97%	178	154	

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Bronchiolitis*	6 months	7000	7	24hrs	Yes	72	45	82%	94%	168	121	
Pre-term**	1 day	1800	6	5hrs	Yes	52	0	91%	0	0	0	Died sepsis
Pre-term/ apnoea**	1day	2000	6	24hrs	Yes	62	42	72%	94%	160	156	Abdominal distention
Pre-term/ apnoea**	1day	2200	6	24hrs	Yes	68	60	84%	92%	176	147	Referred to higher centre
Pneumonia**	3 month	3600	7	28hrs	Yes	68	50	84%	97%	166	141	
Pre -term/ IUGR**	3 days	1400	7	48hrs	Yes	108	55	80%	94%	158	136	
Broncho-pneumonia**	1 month	4000	6	18hrs	Yes	90	55	82%	94%	205	160	
Broncho-pneumonia**	2 months	3500	6	12hrs	yes	90	58	76%	97%	158	144	
Birth asphyxia***	2 days	3500	7	72hrs	Yes	80	54	83%	94%	130	120	

Note: *Shishu Childrens Hospital, **Mymansingh Community Hospital, ***Joyramkura.

Conclusion

The 'fish tank' apparatus can support ventilation and improve oxygenation in infants with respiratory distress in resource poor-settings, dramatically reducing costs. We used expensive nasal prongs but Chisti et al have demonstrated, also in Bangladesh, that inexpensive 'high flow' tubing with In inbuilt nasal prongs can be modified to produce CPAP by immersing one limb of the tubing beneath water (Figure 2) [7]. We have not yet established how long the 'fish tank' pumps will continue to work but experience suggests continued function for many months. Costs of replacement would be reduced by bulk buying. Anecdotally, 'fish tank' pumps have been trialled by one of the authors in Papua New Guinea and Madagascar. Indications have included severe pneumonia, bronchiolitis, apnoea of prematurity, as well as neonatal respiratory distress. They have been demonstrated to be efficient but the busyness of the hospitals has, thus far, precluded sufficient documentation for publication. Our study is thus limited by lack of local resources including access to blood gas machines, as well as demands of service load. Nevertheless, in 'fish tank' or other small pumps would appear to offer the possibility of CPAP in resource poor settings.

Competing Interests

Nil.

Funding Source

Department of Paediatrics, Western Sydney University.

Contribution

- A Lyneham, M Porter, M Cooper and J Whitehall. Project design and implementation. Data collation and preparation of submissions.
- Clinical application and data collection. A Lyneham (CNS), M. Cooper (RN), Dr. Khandakar Ashikur Zaman, Dr. Lucy Daring, Dr. S Liza.

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