Elective nasal continuous positive airway pressure to support respiration after prolonged ventilation in infants after congenital cardiac surgery

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ABSTRACT

Background : **We sought to compare the effectiveness of oxygen (O_2) treatment administered by an O_2 mask and nasal continuous positive airway pressure (NCPAP) in infants after congenital cardiac surgery.**

Methods : **In this retrospective observational study, 54 infants undergoing corrective cardiac surgery were enrolled. According to the anesthesiologist's preference, the patients ventilated for more than 48 h were either put on NCPAP or O_2 mask immediately after extubation. From pre-extubation to 24 h after treatment, arterial blood gas and hemodynamic data were measured.**

Results : **After 24 h of NCPAP institution, the patients showed a significant improvement in oxygenation compared to O_2 mask group. Respiratory rate (per minute) decreased from 31.67 ± 4.55 to 24.31 ± 3.69 ($P < 0.0001$), PO_2 (mmHg) increased from 112.12 ± 22.83 to 185.74 ± 14.81 ($P < 0.0001$), and PCO_2 (mmHg) decreased from 42.88 ± 5.01 to 37.00 ± 7.22 ($P < 0.0076$) in patients on NCPAP. In this group, mean pediatric cardiac surgical Intensive Care Unit (PCSICU) stay was 4.72 ± 1.60 days, with only 2 (11.11%) patients requiring re-intubation.**

Conclusion : **NCPAP can be used safely and effectively in infants undergoing congenital cardiac surgery to improve oxygenation/ventilation. It also reduces the work of breathing, PCSICU stay, and may reduce the likelihood of re-intubation.**

Keywords : Congenital cardiac surgery, infants, nasal continuous positive airway pressure, oxygen mask

INTRODUCTION

Positive pressure ventilation affects not only gas exchange but may also disturb cardiovascular function by altering lung volumes and intrathoracic pressure. Hence, the use of low positive airway pressures, especially low-positive end-expiratory pressure (PEEP), is commonly suggested. Recently, there has been an increasing interest in early extubation following cardiac surgery. However, some patients may need respiratory support for a prolonged

Access this article online

Quick Response Code:

Website: www.annalspc.com

DOI: 10.4103/0974-2069.197055

How to cite this article: Gandhi H, Mishra A, Thosani R, Acharya H, Shah R, Surti J, *et al*. Elective nasal continuous positive airway pressure to support respiration after prolonged ventilation in infants after congenital cardiac surgery. Ann Pediatr Card 2017;10:26-30.

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period of time following cardiac surgery, and sometimes, the use of relatively high pressure in the form of continuous positive airway pressure (CPAP) may prove to be beneficiary even after extubation.[1,2]

The relaxation volume of the infant thorax is smaller than the adult, resulting in a lower functional residual capacity (around 15% of vital capacity compared to 35% in the adult). This imposes a clear disadvantage in terms of alveolar stability due to an increased tendency to collapse, especially in the sedated infant during ongoing mechanical ventilation after cardiac surgery.[3]

Neonates with heart disease can experience acute respiratory failure (ARF) as a result of underlying cardiac disease or secondary to acute lung injury after cardiac surgery. This distinct subgroup is frequently characterized by longer ventilation and Intensive Care Unit (ICU) stay. Conventionally, ARF in postcardiac surgical children is managed with endotracheal intubation and mechanical ventilation. This increases the risk of barotrauma and ventilator-associated pneumonia.[4] Use of noninvasive ventilation (NIV) in pediatric cardiac patients as an alternative ventilator support is not well established. In contrast, numerous reports on adults and children more than 1 year of age favor the use of NIV in diverse clinical scenarios.[5-7]

However, the literature reporting the efficacy of NIV therapy in infants with heart disease is scarce. Noninvasive positive airway pressure ventilation is easy to setup and wean, more comfortable, and less expensive. Technical problems such as interface and ventilator equipment, unknown effects on cardiopulmonary interaction, risk of aspiration, and effects on chest wound healing frequently limit the use of NIV for infants with heart disease.

The role of NIV and use of bi-level positive airway pressure (BiPAP) nasal CPAP (NCPAP) support were previously evaluated in pediatric patients with status asthmaticus[7,8] and in pediatric patients undergoing cardiac surgery,[9] respectively. Still it had not been specifically evaluated in infants undergoing cardiac surgery. Hence, the practice of NCPAP usage in infants is relatively low and often subjected to difference of opinion. We designed a retrospective study with an aim to compare the efficacy of O_2 mask and NCPAP in infants requiring prolonged ventilation (>48 h) after cardiac surgery.

METHODS

Patient selection

This was a retrospective observational study, approved and cleared by the Institutional Ethics Committee. From January 2013 to December 2013, a total of 372 infants underwent different cardiac surgeries. From this, 54 patients required prolonged ventilation (>48 h), and out of them, 36 pediatric patients were placed on O_2 mask after extubation and 18 patients were placed on NCPAP. The choice of patient for NCPAP or O_2 was basically the anesthesiologist's decision. Patients with re-operation, perioperative cardiac arrest, severe organ dysfunction (renal and liver), severe neurological disease, abdominal distention, or swallowing reflex abnormality were excluded from the study.

Oxygen mask or nasal continuous positive airway pressure application

After cardiac surgery, 54 patients required invasive ventilation for more than 48 h. In this study, 36 patients after prolonged ventilation were put on O_2 mask with 3–4 L/min O_2 flow and 18 patients were put on NCPAP (by nasal cannula with NCPAP circuit; FANEM, Sao Paulo, Brazil). We used noninvasive NCPAP mode (GE Engstrom Carestation ventilator) in pediatric setup of ventilator, with an initial NCPAP setting for all with FiO_2-50%, PEEP - 5, bias flow - 8.0 l, and trigger - 1.0. If patients did not respond to these settings, PEEP and FiO_2 were increased subsequently. A backup rate was added to assist with inadequate minute ventilation or apnea. The patients were closely monitored in terms of vital signs, oxygen (O_2) saturation, respiratory rate, tidal volume, breathing effort, chest retraction, use of accessory respiratory muscles, patient–ventilator synchrony, abdominal distention, aspiration, sedation for anxiety, blood gas, and chest X-ray for lung status and pneumothorax. The indications for terminating O_2 mask or NCPAP included no obvious relief of dyspnea, no significant improvement of blood gas, hemodynamic instability, vomiting, and respiratory tract obstruction with secretions.

Statistical analysis

Statistical analysis was performed using SPSS software, Version 20.0 (IBM Corp., Chicago, IL, USA). Categorical variables were presented as numbers and percentages and analyzed using the Chi-square test. Continuous variables were assessed for normal distribution and presented as mean and standard deviation. Continuous variables were compared using the Student's *t*-test for normally distributed variables and the Mann–Whitney U-test for non-normally distributed variables. The level of significance was accepted at $P < 0.05$.

RESULTS

In this retrospective study, 54 infants required prolonged ventilation after cardiac surgery. Out of these, 36 patients were put up on O_2 mask and 18 patients were directly put on noninvasive NCPAP. The demographic data in both groups (age, gender, surgery type, bypass time, and cross clamp time) were comparable [Table 1].

Comparison of hemodynamic parameters between pre- and post-extubation at various time intervals in both the groups is shown in Table 2. After 24 h of treatment, the respiratory rate decreased significantly in the NCPAP group (pre-extubation; 31.67 ± 4.55 vs. after 24 h; 24.31 ± 3.69, $P < 0.05$) as compared to O_2 mask group (pre-extubation; 33.22 ± 3.65 vs. after 24 h; 34.49 ± 5.20), while heart rate (pre-extubation; 151.61 ± 20.13 vs. after 24 h; 140.16 ± 18.58, $P = 0.0851$ in NCPAP group) and (pre-extubation; 141.53 ± 20.96 vs. after 24 h; 139.67 ± 22.55, $P = 0.7181$ in O_2 mask group), mean atrial pressure (pre-extubation; 51.82 ± 9.14 vs. after 24 h; 47.5 ± 7.87, $P = 0.1379$ in NCPAP group and pre-extubation; 51.77 ± 10.87 vs. after 24 h; 48.80 ± 9.92, $P = 0.2300$ in O_2 mask group), central venous pressure rate (pre-extubation; 7.61 ± 3.94 vs. after 24 h; 9.83 ± 2.97, $P = 0.0647$ in NCPAP group and pre-extubation; 7.78 ± 2.59 vs. after 24 h; 7.96 ± 3.32, $P = 0.7983$ in O_2 mask group) were comparable [Table 2].

The improvement in both the groups was further compared according to their arterial blood gas parameters and the data are shown in Table 3. There was significant improvement in PO_2 after 24 h in the NCPAP group (pre-extubation; 112.12 ± 22.83 vs. after 24 h; 185.74 ± 14.81, $P < 0.0001$) compared to the O_2 mask group (pre-extubation; 110.38 ± 34.14 vs. after 24 h; 135.18 ± 46.85, $P < 0.05$). PCO_2 was significantly decreased in NCPAP group after 24 h (pre-extubation; 42.88 ± 5.01 vs. after 24 h; 37.00 ± 7.22, $P < 0.05$) as compared to O_2 mask group (pre-extubation; 41.83 ± 6.02 vs. after 24 h; 40.23 ± 9.74). pH in NCPAP group after 24 h (pre-extubation; 7.34 ± 0.14 vs. after 24 h; 7.43 ± 0.65) was comparable to O_2 mask group (pre-extubation; 7.32 ± 0.13 vs. after 24 h; 7.45 ± 0.06).

In this study, the number of patients requiring re-intubation was significantly ($P = 0.049$) lower in NCPAP group (11.11%) as compared O_2 mask group (41.67%) [Table 4]. Pediatric cardiac surgical ICU stay in NCPAP group (4.72 ± 1.60) was less compared to O_2 mask group (7.11 ± 1.19, $P < 0.0001$), which is highly significant. Mortality was comparable in both the groups ($P = 0.868$).

Table 1: Patient characteristics

Parameters	NCPAP group (*N*=18)	O_2 MASK group (*N*=36)	*P* value
Age (days)	67.05±53.95	100.5±97.33	0.1817
Gender			
(i) Male	15 (83.3)	26 (72.2)	0.5737
(ii) Female	3 (16.7)	10 (27.8)	
Weight	3.71±0.74	3.51±0.96	0.435
Surgery type			
(i) VSD Closure	1	4	0.8682
(ii) VSD Closure + other associated	1	4	0.8682
(iii) ICR	0	2	0.7989
(iv) BDG	0	2	0.7989
(v) AVCD Repair	2	0	0.2027
(vi) TAPVC Repair	6	8	0.583
(vii) Arterial swich operation	6	13	0.9197
(viii) Senning	1	1	0.8257
(ix) Trancous repair	1	1	0.8257
(x) ALCAPA	0	1	0.6996
Bypass time	119±56.249	118.38±54.61	0.969
Cross clamp time	80.88±46.52	73.205±38.66	0.528

NCPAP: Nasal continuous positive airway pressure, O_2: Oxygen mask, VSD: ventricular septal defect, ICR: intracardiac repair, BDG: Bidirectional Glenn shunt, AVCD: Atrioventricular canal defect, TAPVC: Total anomalous pulmonary venous connection, ALCAPA: Anomalous left coronary artery from the pulmonary artery

DISCUSSION

In children, complex congenital heart surgery performed with cardiopulmonary bypass may be associated with pulmonary edema, pneumonia, bleeding, and atelectasis, during the postoperative period. Such patients may require prolonged ventilation (more than >48 h) and develop respiratory insufficiency after extubation. In our study, we have retrospectively compared the outcome of O_2 mask and NCPAP in infants undergoing complex congenital heart surgery. Clinical response was associated with improvement of patients' clinical condition and arterial blood gas.[6]

NCPAP is useful in improving the management of ARF in children.[10-12] Noninvasive positive pressure ventilation is superior to standard therapy in preventing intubation and reducing mortality.[8] NCPAP ventilation for the delivery of inspiratory pressure has been shown to reduce the work of breathing. The flow-triggered NCPAP system can decrease expiratory work of breathing and

Table 2: Clinical variables before and after institution of nasal continuous positive pressure (NCPAP) group or oxygen (O_2) mask group

Parameters	Heart rate (/minute)		Mean artial pressure (mmHg)		Central venous pressure (mmHg)		Respiration rate/minute	
	NCPAP group	O_2 mask group	NCPAP group	O_2 mask group	NCPAP group	O_2 mask group	NCPAP group	O_2 mask group
Pre extubation (T_1)	151.61±20.13	141.53±20.96	51.82±9.14	51.77±10.87	7.61±3.94	7.78±2.59	31.67±4.55	33.22±3.65
After 2 hrs (T_2)	158.72±17.52	144.05±21.52	51.29±10.81	56.25±19.25	8.88±3.63	7.25±3.95	28.32±3.35*	31.66±5.48
After 4 hrs (T_3)	145.72±18.76	139.38±22.26	50.22±9.25	56±14.26	8.58±3.10	7.08±3.85	25.67±5.60*	34.56±4.14
After 12 hrs (T_4)	135.26±17.28*	135.58±25.22	52.78±10.85	47.76±9.39	9.23±3.03	7.35±3.74	26.22±4.12*	33.78±3.59
After 24 hrs (T_5)	140.16±18.58	139.67±22.55	47.5±7.879	48.80±9.921	9.83±2.97	7.96±3.32	24.31±3.69*	34.49±5.20

*: $P<0.05$

Table 3: Blood gas before and after institution of nasal continuous positive pressure (NCPAP) group or oxygen (O_2) mask group

Parameters	PO_2 (mmHg)		PCO_2 (mmHg)		PH		SPO_2 (Percentage)	
	NCPAP group	O_2 mask group	NCPAP group	O_2 mask group	NCPAP group	O_2 mask group	NCPAP group	O_2 mask group
Pre extubation (T_1)	112.12±22.83	110.38±34.14	42.88±5.01	41.83±6.02	7.34±0.14	7.32±0.13	96.00±2.24	95.39±2.70
After 2 hrs (T_2)	139.87±24.24*	131.96±31.80*	38.25±4.18*	40.64±8.82	7.42±0.12	7.45±0.05*	97.25±2.29	96.03±2.24
After 8 hrs (T_3)	149.40±22.08*	134.96±39.30*	37.25±4.66*	38.14±6.22*	7.45±0.12*	7.43±0.05*	97.50±1.96*	96.56±1.97*
After 16 hrs (T_4)	169.15±20.75*	136.50±40.24*	39.58±4.37	39.65±5.37	7.44±0.08*	7.42±0.08*	98.58±1.31*	97.14±2.25*
After 24 hrs (T_5)	185.74±14.81*	135.18±46.85*	37.00±7.22*	40.23±9.74	7.43±0.65	7.45±0.06*	99.08±0.95*	97.17±2.27*

PO_2 : Values of partial pressure of oxygen, PCO_2 : Values of partial pressure of carbon dioxide, PH : potential of Hydrogen, SPO_2 : Peripheral capillary oxygen saturation, *: P<0.05

Table 4: Post operative parameter

Parameters	NCPAP group (*n*=18)	O_2 mask group (*n*=36)	*P* value
Number of patients required reintubation	2 (11.11%)	15 (41.67%)	0.049*
PCSICU stay	4.72±1.60	7.11±1.19	<0.0001*
Mortality	1 (5.55%)	4 (11.11%)	0.868

PCSICU : Padiatric cardiac surgical intensive care unit

improve patient comfort. The NCPAP ventilator support system offers a backup ventilator mode for machine breath in the event of apnea.

We have observed that NCPAP was most effective in patients with prolonged ventilation and respiratory muscle fatigue. We routinely extubated the patients after cardiac surgery as early as possible, if they were hemodynamically stable only. Otherwise, prolonged mechanical ventilation was used for the patients with severe underlying disease.

NCPAP ventilation can result in marked decrease in heart rate after 12 h, respiratory rate after 24 h, and improvement in gas exchange (PO_2 after 24 h and PCO_2 after 24 h). In this study, re-intubation rate and ICU stay were less in NCPAP group compared to the O_2 mask group. These improvements in NCPAP group were due to positive pressure ventilation as compared to negative pressure ventilation in O_2 mask group. Positive pressure helps in reducing the work of breathing and alleviates the respiratory muscle fatigue.[6,13]

In accordance with our study, Zhang *et al.*[9] had also used safely and effectively BiPAP in children after cardiac surgery to improve oxygenation, ventilation, and to reduce the work of breathing and re-intubation. We recommend the consideration of the use of noninvasive NCPAP ventilation as an alternative strategy to invasive airway support in patients with prolonged mechanical ventilation, especially those who are dependent on airway support and are difficult to be weaned from the ventilator.[14,15]

Study limitations

This was a retrospective analysis of records. Patients were not randomized and therefore, there are several potential sources of bias in allocation to NCPAP versus O_2 mask. We acknowledge this limitation. The true incremental value of NCPAP can only be determined through a randomized controlled trial. The data from this study can help design a large prospective randomized controlled trial.

CONCLUSION

We conclude that NCPAP is useful in improving the ventilation and preventing ARF in infants after cardiac surgery. This technologically simple, noninvasive, cheap, and safe way to provide respiratory support is suitable after prolonged ventilation in developing countries, where facilities for pediatric intensive care and ventilatory support are inadequate.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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