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Original Article

Outcome of Improvised Bubble Continuous Positive Airway Pressure (bCPAP) in Respiratory Distress Syndrome (RDS) and Factors Associated with its Failure: A Prospective Observational Study

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Abstract

Introduction: Bubble CPAP (bCPAP) is the standard treatment for newborn with RDS but is challenged by availability of proper bCPAP delivery devices. The improvised bCPAP using modified nasal prong with expiratory limb immersed in water is commonly used to deliver pressurized air to the neonate's lungs. The primary objective of the study was to evaluate effectiveness of improvised bCPAP in treating Respiratory distress syndrome (RDS) and to identify factors that may be associated with its failure.

Methods: In this prospective observational study, all consecutively born preterm neonates delivered before 37 weeks of gestation, admitted to the neonatal intensive care unit (NICU) with diagnosis of RDS and needed bCPAP were included in the study. Early rescue surfactant was given according to NICU protocol of the hospital. Those neonates failed to improve despite treatment with Continuous Positive Airway Pressure (CPAP) and needed MV within 96 hours of life are considered as CPAP failure (CPAP-F).

Results: 119 preterm newborn with mean gestational age was 31.95 ± 2.05 weeks and birth weight 1614.33 ± 454.32 gm were enrolled. bCPAP was successful in 22 (18.5%) preterm infants. The mean duration of Continuous Positive Airway Pressure (CPAP) was 61.21 ± 41.81 hours and NICU stay was 12.34 ± 8.12 days. Surfactant was given in 51 (42.9%) and mortality rate was 17 (14.29%). Multivariable logistic regression analysis showed gestational age less than 32 weeks 0.534 (95%CI: 0.340-0.839) and pneumothorax 22 (95%CI: 2.122 - 228.070) are independent risk factors associated with CPAP-F.

Conclusions: Improvised bCPAP is effective in the management of respiratory distress syndrome (RDS). Pneumothorax and gestational age < 32 weeks are independent risk factor for its failure.

Introduction

RDS is an important cause of morbidity and mortality among preterm babies. The standard treatment for RDS involves using CPAP, which delivers pressurized air to the lungs to improve oxygenation and support breathing. CPAP has been shown to reduce mortality risk by 48%[1] and decrease the need for surfactant and mechanical ventilation by about 50%.[2] World Health Organization (2020) recommends early initiation of CPAP for the preterm babies with respiratory distress.[3] However, in resource-limited settings, there may be challenges in accessing standard CPAP machines, circuits, and skilled personnel for newborn monitoring, leading to the need

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for innovative solutions. Therefore, improvised bubble CPAP (bCPAP) is frequently made locally for CPAP delivery by using nasal prong where one of its inlet tubes is cut and connected with larger size nasogastric tube forming expiratory limb which is immersed in water filled in cylindrical, transparent bottles. The length of expiratory tube immersed in water corresponds to the desired bCPAP in cm water which increases the functional residual capacity and lowers work of breathing.[4,5]

The effectiveness of locally made bCPAP has been documented in various studies.[6,7] Since the nasal prong is for delivery of low flow oxygen with only bubble humidification, when flow increases the humidification provided is not adequate and the oxygen is not heated too. This results in dryness of nasal mucosa and interfere with mucociliary clearance which cause discomfort to patient, increases chance of infection, might increase respiratory effort, and increases the chance for intubation.[8,9] Thus, a prospective observational study was designed to evaluate the outcome of improvised bCPAP for the treatment for RDS and to identify the factors associated with its failure. By analyzing the outcomes and potential factors contributing to success or failure, the study aimed to shed light on the use of this low-cost and easily accessible alternative in managing RDS in resource-limited settings.

Methods

This is a study on the outcome of preterm infant at Tribhuvan University Teaching Hospital (TUTH), Maharajgunj, Kathmandu, Nepal, conducted over two years from April 2019 to April 2021. All neonates delivered before 37 weeks, having respiratory distress and requiring CPAP as a primary respiratory support within six hours and for at least for 24 were enrolled in the study. The neonates were excluded if they were < 22 weeks or < 500 gm, had perinatal asphyxia, had major or life threatening congenital abnormality, suspected heart disease in antenatal echocardiography, delivered through meconium stained liquor, confirmed diagnosis of congenital pneumonia or early onset (within 72 hours) sepsis. CPAP as primary respiratory support was given for following newborns:

- For newborns < 30 weeks' gestation and less than 1500 gm who do not need intubation for stabilization, were started on prophylactic CPAP immediately after birth even in absence of signs of respiratory distress.[10]
- For newborn > 30 weeks gestation and more than 1500 gm, they were observed for signs of respiratory distress using Silverman's Anderson scale (SAS). If they developed any signs of respiratory distress present, they were put on oxygen by headbox. If RDS score is ≥ 3 with head box oxygen, early CPAP was started.

Babies were monitored for the signs of respiratory distress using SAS and followed up until discharge. A detailed history, clinical examination and hospital course were recorded in pre designed study performa. Neonates started on CPAP were re-assessed every 15 minutes. CPAP was increased upto 7 cm H_2O unless SAS is ≤ 3. Even after bCPAP of at least 7 cm for at least 15 minutes, if the infant requires $FiO_2 > 0.30$ to maintain oxygen saturation less than 90% or SAS remain > 3, early rescue surfactant was given. The SRT was given within two hours after birth. Early caffeine was given for all babies < 30 weeks or < 1500 gm preterm infant receiving CPAP from birth. Mechanical ventilation was started for babies with SAS > 4, persistent apnea, $SpO_2 < 90\%$ at FiO_2 of 60% or pH < 7.2, $pCO_2 < 60$ mm Hg in ABG.[11] Those babies who improve with this treatment are considered as CPAP success (CPAP-S). Those neonates who failed to improve despite treatment with CPAP and needed MV within 96 hours of life are considered as CPAP failure (CPAP-F). Data collected were entered into SPSS version 26 for analysis. The detailed descriptive analysis of various outcome parameters and complications were done. Student t-test was used to compare continuous variables and Chi-Square test applied to compare categorical variables between CPAP-S and CPAP-F group. Multivariable logistic regression analysis was done to determine independent factors for CPAP-F.

Results

During the study period, 168 newborn developed RDS. Among them 47 were excluded due to various reasons and 119 newborns managed using bCPAP were analyzed for the primary outcome (Figure 1).

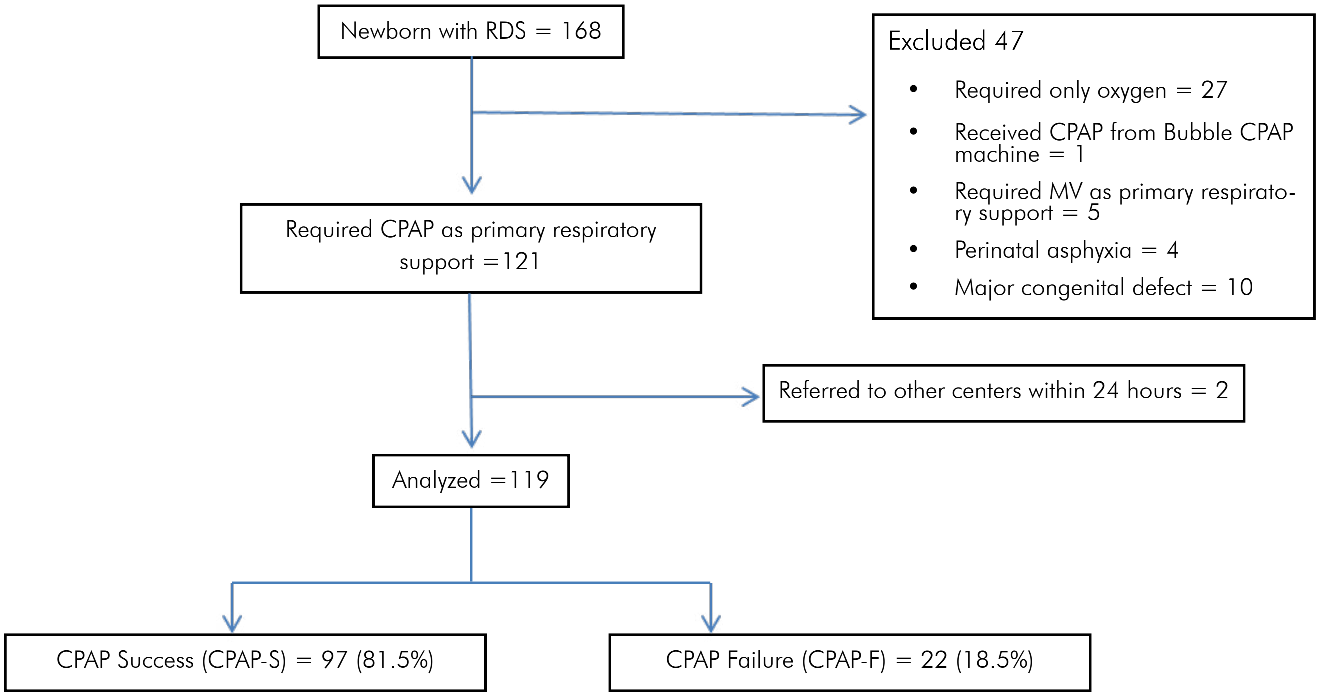

Figure 1: Study flow chart

The baseline characteristics of the study population has been depicted in the Table 1.

Comparative analysis of preterm infants who were successfully weaned (CPAP-S) and who failed in bCPAP (CPAP-F) is summarized in Table 2. The incidence of CPAP failure was 22 (18.5%) and most (59.09%) of them were < 32 weeks GA. The proportion of neonates who developed ROP and BPD were 5 (4.2%) and 2 (1.68%) respectively. Similarly, SRT was given in 51 (42.9%) and significantly higher proportion of newborn requiring SRT had CPAP failure (38.15% Vs 63.63%). Incidence of pneumothorax was also significantly higher in CPAP-F group (1.03% Vs 22.72%). The mean duration of CPAP was 61.21 ± 41.81 hours. In infants surviving till discharge, mean duration of NICU stay was 12.34 ± 8.12 days. The overall mortality was 17 (14.29%) and was significantly higher in the CPAP-F group (7.22 Vs 45.45%).

Univariable analysis showed the gestational age less than 32 weeks, need of SRT and occurrence of pneumothorax are associated with failure of bCPAP. Multivariable analysis showed that gestational age {OR 8.63 (95% CI: 1.71-43.57)} and pneumothorax {OR 22 (95% CI: (2.122 - 228.070)} are the independent antenatal and postnatal risk factors for failure of CPAP respectively (Tables 3 and 4).

Table 1: Comparison of baseline characteristics between CPAP-S and CPAP-F group

Variables	Total 119 (100%)	CPAP success 97 (81.5%)	CPAP failure 22 (18.5%)	P value
Mean Birth weight (gm) ± SD	1614.33 ± 454.32	1586.20 ± 420.02	1555.35 ± 503.96	0.81
Mean Gestational age (± SD)	31.95 ± 2.05	32.13 ± 1.91	31.14 ±2.48	
Gestational age				
34 to < 37	34 (28.6)	27 (27.83)	7(31.81)	0.06
32 to > 34	37 (31.1)	35 (36.08)	2(9.09)	
28 to < 32	46 (38.7)	34 (35.05)	12 (54.54)	
< 28	2 (1.7)	1 (1.03)	1(4.5)	
Gestational age				
≥ 32 weeks	71 (59.66)	62 (63.91)	9 (40.91)	0.04
< 32 weeks	48 (40.33)	35 (36.09)	13(59.09)	
Birth weight Category				
> 1.5 Kg	68 (57.15)	58 (59.79)	10 (45.45)	
1 - 1.5 kg	42 (35.30)	32 (32.98)	10 (45.45)	0.49
< 1 kg	9 (7.5)	7 (7.22)	2 (9.09)	
Birth weight category				
> 1.5 Kg	68 (57.15)	58 (59.79)	10 (45.45)	0.22
≤ 1.5 kg	51 (42.86)	39 (40.20)	12 (54.54)	
Mode of delivery LSCS	82 (68.9)	70 (72.17)	12 (54.54)	0.10
Mean Maternal age (± SD)	29.16± 4.85	29.28 ± 4.21	28.66 ± 4.56	0.61
Multigravida	66 (55.5)	54 (55.67)	12 (54.54)	0.73
Pregnancy induced hypertension (PIH)	34 (28.6)	28 (28.86)	6 (27.27)	0.88
Gestational diabetes mellitus (GDM)	11 (9.2)	10 (10.31)	1 (4.54)	0.39
Antepartum hemorrhage (APH)	14 (11.8)	10 (10.31)	4 (18.18)	0.31
Maternal Heart disease	4 (3.4)	2 (2.07)	2 (9.09)	0.09
SGA according to WHO growth chart	59 (49.58)	51 (52.57)	8 (36.36)	0.17
Male	49 (41.18)	40 (41.23)	9(40.91)	0.32
Twins / triplet	10 (8.41)	9 (9.27)	1 (4.5)	0.47
PROM	22 (18.49)	16 (16.5)	6 (27.27)	0.24
Antenatal corticosteroid (ANS) completed	65 (54.60)	54 (55.67)	11 (50)	0.63
Resuscitated at birth	17 (14.29)	13 (13.41)	4 (18.18)	0.26

Table 2: Outcome of CPAP in two groups

Variables	Total (N=119) (%) (100%)	CPAP Success (N=97) (%) (81.5%)	CPAP failure (N) (%) 22 (18.5%)	P value
Need for SRT	51 (42.85)	37 (38.15)	14 (63.63)	0.006
Pneumothorax	6 (5.05)	1 (1.03)	5 (22.72)	0.01
Apnea	14 (11.77)	11 (11.34)	3 (13.64)	0.71
BPD	2 (1.68)	2 (2.06)	0	0.49
Sepsis	45 (37.82)	35 (36.08)	10 (45.45)	0.42
Shock	23 (19.33)	16 (16.5)	7 (31.8)	0.10
ROP	5 (4.21)	4 (4.12)	1(4.54)	1
Mean Duration of CPAP in hours ± SD	61.21 ± 41.81	64.31 ± 40.53	47.51 ± 45.52	0.08
Mean Duration of respiratory support in hours ± SD	162.97 ± 127.99	156.38 ± 131.06	192.01 ± 111.54	0.24
Mean Duration of NICU stay ± SD	12.34 ± 8.12	12.62 ± 7.91	11.05 ± 9.07	0.42
Mortality	17 (14.29)	7 (7.22)	10 (45.45)	0.01

Table 3: Multivariate logistic regression of antenatal factors associated with CPAP failure.

	Adjusted OR	95% CI	P value
Maternal age	0.95	0.81 - 1.12	0.51
Parity	1.350	0.28 - 6.45	0.707
Delivery Mode LSCS	2.306	0.50 - 10.54	0.281
Gestational age	.534	0.34 - 0.83	0.006
Maternal PIH	.647	0.14 - 2.91	0.570
Maternal Heart disease	.042	0.002 - 1.03	0.053
Maternal GDM	.265	0.01 - 3.91	0.334
PROM	.468	0.10 - 2.009	0.307
Twin Pregnancy	1.80	0.11 - 27.69	0.67
APH	3.91	0.23 - 64.63	0.34

Table 4. Multivariate logistic regression of neonatal factors associated with CPAP failure.

	Adjusted OR (95% CI)	P value
Male	0.59 (0.19- 1.83)	0.36
Weight of infant < 1.5 kg	1.92 (0.44 - 8.36)	0.38
Mean gestational age (weeks)	1.318 (0.37- 4.62)	0.66
Pneumothorax	22 (2.12 - 228.07)	0.001
SRT	3.076 (0.929- 10.18)	0.06
ANS	0.62 (0.19 - 2.03)	0.43
SGA	2.23 (0.53- 9.30)	0.26
Need of resuscitation at birth	0.43 (0.10- 1.77)	0.24
Apnea	1.03 (0.20- 5.23)	0.96
Sepsis	0.58 (0.16-2.04)	0.39

Discussion

This study describes the short term outcome of the early improvised bCPAP therapy with selective administration of surfactant in 119 premature newborn with RDS. The incidence of CPAP failure was 22 (18.5%) with 13 (59.09%) occurring in ≤ 32 weeks GA. The proportion of neonates who required surfactant was 51 (42.9%), who developed ROP was 5 (4.2%) and who met with mortality was 17 (14.3%).

CPAP failure depends on the device use and ranges from 14% to 40%.[6,12-17] However, the rate of CPAP failure in babies with higher gestational age and birth weight is higher compared to studies where bubble CPAP machines were used. In a retrospective study by Ammari et al[18], the failure rate of bubble CPAP was 24% in babies < 1250 g and 50% in babies < 750 g. None of the baby > 30 weeks gestation failed bCPAP. In a case-control study by Boo et al,[19] out of 97 preterm babies with RDS on ventilator CPAP or bCPAP, 38% failed CPAP and required mechanical ventilation. The difference in CPAP failure rate in various studies may be attributed to birth weight and gestation of infants enrolled, type of CPAP devices and nasal interface, variation in NICU protocol of starting CPAP, SRT or MV etc.

Jeya Balaji RV et al[20] studied the outcome of bCPAP as primary respiratory support in 70 preterm newborns ≤ 32 weeks with RDS where CPAP failed in 30%, SRT was needed in 18.6%, ROP and mortality were 37.1% and 7.1% respectively. Comparing this finding among the preterm of same gestational age, the incidence of CPAP failure, mortality and need for SRT was much higher in the present study. One of the reasons behind the higher incidence could be due to difference in the definition of CPAP failure criteria where they used ABG criteria in contrast to clinical Silverman scoring used in the present study. However, this difference could even be due to difference in CPAP delivery device and higher incidence of hospital acquired sepsis in our setup. The overall incidence of sepsis in this study was 45 (37.81%) which is quite high compared to the finding of the study done in Korea[21] and Greece.[22] Delivery of oxygen in this type of CPAP does not provide proper humidification and heating of oxygen resulting in dryness of nasal mucosa and interfere with mucociliary clearance which might have increased rate of infection in the present study. Mortality rate due to sepsis among babies with RDS observed in this study is comparable to other studies and ranges from 25 to 49% indicating importance of infection prevention practices for improving preterm survival.[23, 24]

In the present study, CPAP-F is commonly associated with gestational age less than 32 weeks, pneumothorax and death. Overall pneumothorax rate was 6% which is comparable to the rate in bCPAP delivered by machine. Pneumothorax rate was 10.58% with the use of Fisher and Paykel bCPAP and is commonly associated with mortality in CPAP-F group in the similar study done by Arora V et al.[15] However, they also identified partial or no response to antenatal steroids (ANS), white-out on the chest X-ray, Silverman scoring > 6 or FiO2 > 0.4 after 15 - 20 minutes of CPAP, extreme prematurity as predictors of CPAP failure.

In a similar study done by Soomro T et al,[25] weight less than 1.5 kg, RR more than 70, nasal flaring and typical findings of RDS on chest X-rays are independent risk factors for failure of bubble CPAP. However, gestational age is protective against failure. The effectiveness of this improvised CPAP for the newborn of extreme premature newborn need to be confirmed by larger multicentric study.

Ammari et el[17] reported typical findings of RDS on the chest X-ray was an important predictor of bCPAP failure. Chest X-ray was not evaluated in present study as most of the time chest X-ray was taken after surfactant administration and radiologist report was not available for many of them. Since, our NICU protocol for starting respiratory support is based on the clinical monitoring, we did not analyze admission ABG which was not available in many newborns. These are some limitations of this study.

Conclusions

The improvised bCPAP is an effective means of primary respiratory support for management of RDS. This type of CPAP may fail in gestational age less than 32 weeks or with occurrence of pneumothorax. Nearly half of the newborns with CPAP failure die.

Conflict of Interest: None

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