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Effectiveness of improvised bubble CPAP in newborns in resource limited setting (Senegal)

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Abstract: *Introduction:* Neonatal respiratory distress remains a major cause of morbidity and mortality, particularly in resource-limited settings. It is therefore essential to offer simple and accessible solutions such as low-cost, improvised bubble Continuous positive airways pressure (bCPAP).
Objectif: The main objective of this study is therefore to evaluate the efficacy and tolerability of improvised bCPAP in newborns with respiratory distress.
Methods: This descriptive retrospective study was conducted at the Abass Ndao Hospital Centre in Dakar over a period of one year
Results: It covers 98 newborns who received improvised bCPAP. Prematurity was the main risk factor, 80% of the newborns included. The use of improvised bCPAP led to a significant improvement: normalization of respiratory rate in 95% of patients; improvement in oxygen saturation, reduction in the severity of respiratory distress in 85% of infants. Weaning success rate of 74.5%, with a direct transition to ambient air possible in 41% of cases. The average duration of bCPAP use was 5.11 ± 0.82 days. The average length of hospitalisation in our cohort was 12.63 ± 1.10 days. No direct adverse effects attributable to the device were observed.The complications observed and the estimated mortality rate of 25% remain a concern and were mainly related to prematurity and low birth weight.
Conclusion: The implementation of improvised bCPAP appears to be a relevant and effective alternative in resource-limited settings. Its deployment, combined with adequate training of healthcare personnel, is an essential lever for improving neonatal survival in Senegal and other similar environments.

Keywords: Bubble-CPAP; Improvised; Newborns; low settings resources,

Résumé: *Introduction:* A l'échelle mondiale et plus particulièrement dans les pays à ressources limitées, la détresse respiratoire néonatale représente une cause majeure de morbidité et de mortalité néonatale. Face à cette situation, il est essentiel de proposer des solutions simples et accessibles comme le recours à l'utilisation d'un dispositif de CPAP à bulles fabriqué de manière artisanale et à faible coût.
Objectif: L'objectif principal de cette étude est d'évaluer l'efficaci

l'efficacité et la tolérance du bCPAP artisanale chez les nouveau -nés en détresse respiratoire.
Méthodes: Nous avons mené une étude descriptive rétrospective au Centre Hospitalier Abass Ndao à Dakar sur une période d'un an.
Résultats: Durant la période d'étude, 98 nouveau-nés avaient reçu un traitement par bCPAP artisanale. La prématurité était le principal facteur de risque, représentant 80 % des nouveau-nés inclus. L'utilisation du dispositif de bCPAP artisanale a conduit à une amélioration significative : Normalisation de la fréquence respiratoire chez 95 % des patients ; amélioration de la saturation en oxygène ; réduction de la sévérité de la détresse respiratoire chez 85 % des nourrissons. Le taux de réussite du sevrage était de 74,5 %, avec un passage direct à l'air ambiant possible dans 41 % des cas. La durée moyenne d'utilisation de la bCPAP artisanale était de 5,11 ± 0,82 jours. La durée moyenne d'hospitalisation dans notre cohorte était de 12,63 ± 1,10 jour. Aucun effet indésirable direct attribuable au dispositif n'a été observé. Les complications observées et le taux de mortalité estimé à 25 % restent préoccupants et étaient principalement liés à la prématurité et au faible poids de naissance.
Conclusion: La mise en place de la bCPAP artisanale a prouvé son efficacité et sa pertinence dans la prise en charge des détresses respiratoires dans les contextes à ressources limitées. Son déploiement, associé à une formation adéquate du personnel de santé, constituent un levier essentiel pour améliorer la survie néonatale au Sénégal et dans d'autres environnements similaires.

Introduction

In low-income countries, neonatal mortality accounts for a significant proportion of overall infant mortality. According to the World Health Organization (WHO), in 2022, 47% of all deaths among children under five years occurred during the neonatal period[1]. At the same time, the neonatal mortality rate was highest in sub-Saharan Africa, with 27 deaths per 1,000 live births[1]. In Senegal, despite progress in improving maternal and child health, according to the 2023 Demographic and Health Survey (DHS), neonatal mortality remains a persistent challenge: although a downward trend has been observed over the last decade, the rate has fallen from 25 to 23 deaths per 1,000 newborns[2]. Faced with this situation, it is essential to offer simple and accessible solutions. The use of continuous positive airway pressure (CPAP) is recognized as an effective, non-invasive strategy for keeping the airways open, improving respiratory effort and reducing the need for mechanical ventilation [3]. In Senegal, access to standard CPAP devices remains limited due to their high cost and the restricted availability of suitable biomedical equipment [4]. In this context, the use of CPAP, even when manufactured in a low-cost, artisanal manner using simple materials, may be a viable alternative[5]. The main objective of this study is therefore to evaluate the efficacy and tolerability of improvised bubble CPAP (bCPAP) in newborns with respiratory distress.

Methods

The study was conducted in the pediatric department of the Abass Ndao Hospital Centre (CHAN), a level 3 public health facility in Senegal's healthcare system. This single-centre study was conducted over a period of one year (July 2024 to June 2025). It is a retrospective descriptive and analytical study. We included newborns hospitalized in the neonatal unit during the study period who received improvised bCPAP either initially or during their treatment. We excluded newborns with major congenital malformations affecting respiration (e.g. diaphragmatic hernia, uncorrected bilateral choanal atresia, severe pulmonary malformations), major heart disease, and newborns with desaturation requiring immediate intubation without attempting bCPAP. Premature newborns with even mild respiratory distress were immediately placed on improvised bCPAP. However, for full-term newborns, the decision to initiate positive pressure ventilation was based on the severity of respiratory distress, the presence of hemodynamic instability or neurological distress. Newborns from the maternity ward (inborns) were placed directly on bCPAP within one hour of delivery if indicated, whereas bCPAP was initiated in transferred newborns (outborns) within 2 to 7 hours post-delivery[5]. We evaluated quantitative and qualitative variables such as gestational age, trophicity, duration of improvised bCPAP, length of hospitalization, pulse oxygen saturation (SpO_2), respiratory rate, respiratory effort according to the Silverman score, indication for improvised bCPAP, and the occurrence of complications and deaths. We collected data from medical records. Qualitative variables were described in terms of numbers and percentages, while quantitative variables were presented as means ± standard deviation or medians accompanied by their extreme values, depending on the distribution of the data. Ethical considerations: The study was conducted in accordance with confidentiality and medical confidentiality requirements. The data was anonymized before processing. Authorization was obtained for the use of medical records.

Description of the improvised bCPAP

The improvised bCPAP is handmade by trained paramedical staff and contains an oxygen source with an appropriate flow meter (0–15 L/min) and a breathing circuit: 02 ventilation tubes connected in a Y or T configuration (to connect to the patient and the water column), nasal cannulas and an expiratory pressure system with a bottle filled with water (transparent bottle). The immersion depth is checked by measuring the number of centimeters using a tape measure.The system works by immersing the end of the expiratory tube in a column of

water. Oxygen is administered to the newborn via a nasal cannula. The depth of immersion of the expiratory tube determines the continuous positive expiratory pressure (PEEP) applied to the airways: for example, an immersion of 5 cm corresponds to a PEEP of 5 cmH_2O. During exhalation, the air must overcome the hydrostatic resistance of the water column in order to escape, generating bubbling. This phenomenon induces small pressure oscillations called micro-oscillations that propagate to the pulmonary alveoli. These micro-oscillations have several beneficial physiological effects: they help maintain alveolar recruitment, improve gas exchange and oxygenation, reduce respiratory effort and facilitate the drainage of bronchial secretions. As a result, the system combines the effect of stable PEEP with dynamic oscillations that optimize pulmonary ventilation and support respiratory function in newborns, particularly in premature infants with pulmonary immaturity or neonatal respiratory distress syndrome. The quality criteria for generating good PEEP with bCPAP (fig 1):

- The expiratory tube should be immersed in water to a depth of between 5 and 10 cm.
- The expiratory tube should be wide (≥ 8 mm internal diameter) to avoid creating excessive resistance and therefore a higher-than-expected PEEP. The standard length is approximately1.5 m.
- A low-resistance nasal interface.
- Avoid excessive dead space: Long connection tubes can cause CO_2 re-inhalation
- Appropriate gas flow: 8-12 L/min to maintain constant bubbling.
- Monitoring and absence of leaks: Circuit connections must be tight.

Results

Population characteristics

A total of 1,153 newborns were hospitalized during the study period. Among them, 186 newborns (16.1%) had severe respiratory distress enough to require continuous positive airway pressure (CPAP) ventilation. Of these 186 patients, 88 were excluded due to predefined non-inclusion criteria. At the end of this selection process, 98 newborns met all the inclusion criteria and thus constituted the final study cohort. The sex ratio was 1.65. Prematurity was present in 79 cases (81%). Among the premature newborns, 27 (34%) had received antenatal corticosteroid therapy. Of these, 15 had received a full course of treatment, 5 had received only a single dose, and the number of doses was not specified in 7 cases. Newborns with low birth weight (<2500 g) accounted for 79.6%, and 36% of premature infants had intra-uterine growth restriction (IUGR). Vaginal delivery was the most common mode of delivery. In the premature population, 51 (64%) premature infants were born by spontaneous vaginal delivery. Among the newborns, 31.6% had received resuscitation at birth according to the 2020 ILCOR (International liaison Committee on Resuscitation) protocol. Most of the babies were born in our maternity ward (inborn), i.e. 86% (Table 1).

Fig 1: Improvised bCPAP

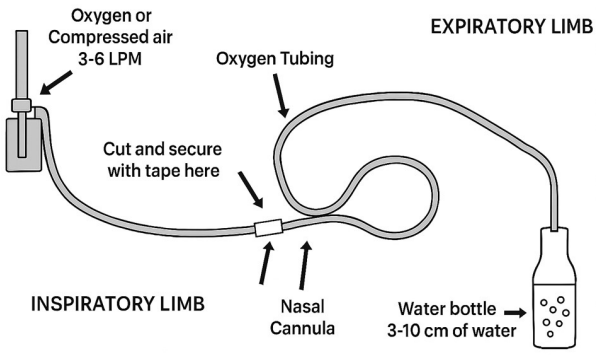

Table 1: Population characteristics

Population features	Number	Percentage (%)
Gestationalage		
< 28 SA	13	13,3
28 – 31 SA + 6 j	37	37,8
32 – 36 SA + 6 j	29	29,6
37 – 41 SA + 6 j	17	17,3
≥ 42 SA	2	2,0
Antenatalcorticosteroidtherapy		
0	52	66
1 dose	5	6
2 doses	15	19
Non	7	9
Birth weigth		
< 2500g	78	79,6
2500g – 3500g	15	15,3
3501g – 4000g	2	2,0
> 4000g	3	3,1

Clinical data

Regarding respiratory rate (RR), 52% of newborns had polypnoea (RR>60 cycles/min) and 27% had bradypnoea (RR<40 cycles/min). On average, preductal saturation (SpO2) (right upper limb) was 89% and postductal saturation (lower limb) was 88% without oxygen delivery. Respiratory distress was classified according to the Silverman score and was moderate in 58% of cases. The most observed signs of respiratory distress were nasal flaring and intercostal retractions. Cyanosis was present in 55.2% of newborns. The most common diagnoses were hyaline membrane disease, apnea of the preterm, early neonatal infection, and perinatal asphyxia (Table 2).

Data on improvised bCPAP

The indications for improvised bCPAP were respiratory distress in 82% of cases, apnoea in 51% of cases, neurological distress (18.3%) and haemodynamic instability (26.5%).The oxygen flow rate varied between 8 and 15 l/min, with an average of 8 l/min, and the immersion depth of the expiratory circuit was generally between 5

and 6 cm. The adverse effects investigated were abdominal distension, nasal ulceration and the occurrence of pneumothorax. None of these events were observed in our newborns. With a P-value <0.0001, normalization of respiratory rate was observed in 95% of newborns. An improvement in respiratory distress was observed in 85% of babies, and only 5% of babies still presented respiratory distress under improvised bCPAP, with saturation increasing from 89% to 98% on average. The average duration of improvised bCPAP was 5 days. Weaning was not initiated in 19 babies, a population represented by newborns whose distress remained severe or who were neurologically or hemodynamically unstable. Weaning from improvised bCPAP was successful in 74.5% of cases. Direct transition to room air was possible in 41% of newborns. The average length of hospitalization was 12 days.The mortality rate was 25%, with 88% of deaths occurring among preterm newborns. Most of these deaths occurred in the context of hemorrhage or complications related to prematurity and low birth weight, such as enterocolitis and severe apnea. The table 3 summarize data.

Table 2: Indications for bCPAP therapy and diagnoses

bCPAP indications and diagnoses	Number	Percentage (%)
Indications		
Respiratorydistress	81	82
Apnea	50	51
Neurologicdistress	18	18,3
Haemodynamicinstability	26	26,5
Diagnoses		
Neonatal sepsis	63	64.29
Hyaline membrane disease	59	60.2
Apnea of the preterm	22	22.45
Perinatal asphyxia	17	17.35
Transient tachypnoea in newborns	10	10.2
Meconium aspiration syndrome	8	8.16

Table 3: General trend under homemade bCPAP

Progress under bCPAP	Without bCPAP (Number)	Under bCPAP (Number)	P-value
Respiratory rate			
<40	27	1	<0,0001
40 – 60	19	95	
> 60	52	2	
Respiratorydistress			P-value
Mild	11	85	<0,0001
Moderate	58	8	
Severe	28	5	
OxygenSaturation			P-value
<90	35	1	<0,0001
90 à 94	24	4	
≥ 95	39	93	

Discussion

Effect of antenatal corticosteroid therapy

In our study, 27 preterm newborns (34%) had received antenatal corticosteroid therapy. This coverage remains insufficient considering international recommendations, which recommend systematic administration to all women at risk of preterm delivery before 34 weeks of gestation, ideally in the form of a full course of betamethasone or dexamethasone [6]. Indeed, Kurt et al. (2025), in a cohort showed that antenatal corticosteroid therapy, even when incomplete, reduced the risk of neonatal pulmonary complications by 42%. In addition, the use of positive pressure ventilation was slightly lower in the group that received corticosteroids (17.3%) compared to the control group (20.1%) [7].Our results are in line with data from the literature, with most respiratory distress cases observed in newborns who had not received any antenatal corticosteroid therapy, while exposed children most often presented with moderate to mild forms. This suggests that, even when partial or incomplete, corticosteroid therapy helps to reduce the severity of respiratory distress and improve response to bCPAP treatment.

Prematurity

The prevalence of prematurity in our cohort was 81%, a result consistent with those reported in the literature. Similar studies conducted in rural areas in Rwanda (71%) and Senegal (69%)confirm that premature infants constitute the population most treated with bubble CPAP ventilation. Respiratory diseases associated with prematurity continue to be a very difficult condition to manage worldwide[8,4]. The CPAP is now recommended by the WHO as the first-line treatment for respiratory management in premature newborns worldwide [6]. In preterm infants, surfactant deficiency leads to decreased lung compliance, alveolar collapse and impaired gas exchange, causing neonatal acute respiratory distress syndrome[9]. bCPAP works by limiting these phenomena through the application of PEEP, which prevents alveolar collapse and promotes endogenous surfactant production[10]. In addition, the mechanical characteristics of newborns (highly compliant chest wall, diaphragmatic weakness, nasal breathing with narrow airways) accentuate respiratory inefficiency. bCPAP helps to compensate for this by stabilizing the chest wall, reducing muscle fatigue and increasing CRF[9]. Finally, in preterm infants, bCPAP also helps to reduce the frequency of obstructive and central apnea by keeping the airways open and modulating respiratory control[11].

Overall progression under improvised bCPAP and overall survival

In our series, the clinical progression of newborns placed under improvised bCPAP was marked by rapid and significant improvement in respiratory parameters. Normalization of respiratory rate was observed in 95% of patients, with a highly significant value ($p < 0.0001$). In addition, an improvement in respiratory distress was observed in 85% of newborns, while only 5% still had residual respiratory distress under bCPAP. These results were accompanied by improved oxygenation: oxygen

saturation increased on average from 89% to 98% after the device was installed. These observations are in line with data in the literature, which confirm the effectiveness of improvised bCPAP, even low-cost versions, in rapidly correcting hypoxemia and reducing respiratory effort [4,8,12-14].In a comparative study between the use of bCPAP and nasal prongs conducted in Malawi in 2014 on a population of premature newborns, significantly higher survival rates were observed with bCPAP compared to oxygen therapy alone, with a notable improvement in clinical signs of respiratory distress [15].Similarly, in a systematic review published by Chisti et al, the use of bCPAP was associated with a reduction in mortality and a decrease in the use of mechanical ventilation compared to simple nasal prongs [16].Our results therefore confirm that improvised bCPAP is an effective and reliable alternative for managing neonatal respiratory distress in resource-limited settings. However, the proportion of babies still experiencing persistent distress (5% in our cohort) highlights the importance of close monitoring, early identification of improvised bCPAP failure, and rapid escalation to mechanical ventilation when necessary. The 25% mortality rate under improvised bCPAP in our study mainly reflects the severity of non-respiratory complications of prematurity and low birth weight, rather than the ineffectiveness of the technique.

A recent article published in June 2025 confirms that globally, 74.3% of neonatal deaths occur in preterm newborns (<37 weeks). According to this study, these deaths are preventable through quality perinatal care (neonatal intensive care, safe oxygen therapy, infection prevention and monitoring of high-risk pregnancies) [17].In our series, the average duration of bCPAP use was 5.11 ± 0.82 days, which is comparable to the data reported in the literature. Indeed, the Nepalese series reported an average duration of 4 ± 1.5 days, which is close to our results [12]. Similarly, the Indian study found an average duration of 4 ± 4 days[5]. This similarity suggests a relative homogeneity of practices and needs for non-invasive ventilatory support in different resource-limited settings. Regarding the length of hospital stay, our cohort had an average of 12.63 ± 1.10 days, which is consistent with the data from the Nepalese series (12 ± 7.5 days)[12]. However, this duration appears to be shorter than that reported in the Indian series (16.8 ± 8 days), probably due to differences in the initial severity of respiratory distress, access to neonatal intensive care, or weaning and hospital discharge protocols [5]. Thus, our results confirm that the duration of bCPAP use and the length of hospital stay observed in our context are in line with the trends reported in other countries, while highlighting the importance of organizational and contextual differences that may influence these indicators.

Conclusion

Improvised bCPAP is a pragmatic and effective solution when resources are limited. Its widespread use, accompanied by appropriate training, represents a major lever for improving the survival of newborns in Senegal and other similar contexts. It is therefore essential to ensure its integration into protocols for the management of neonatal respiratory distress, especially in resource-limited settings, by training paramedical staff in the assembly of the device and its monitoring during use.

References

1. World Health Organisation. Neonatal mortality. Geneva: WHO; 2024 14 March
2. National Agency for Statistics and Demography (ANSD), Ministry of Health and Social Action, ICF. Senegal: Continuous Demographic and Health Survey (EDS Continue) 2023.
3. Myhre J, Immaculate M, Okeyo B, An and M, Omoding A, Myhre L, et al. Effect of Treatment of Premature Infants with Respiratory Distress Using Low-cost Bubble CPAP in a Rural African Hospital. J Trop Pediatr.2016;62(5):385-9.
4. B. Mamadou. Contribution of bubble CPAP in neonatology to the paediatric department of the Pikine National Hospital [Medical thesis]. Dakar: Cheikh Anta Diop University; Dec 2019.
5. Koti J, Murki S, Gaddam P, Reddy A, Reddy MDR. Bubble CPAP for respiratory distress syndrome in preterm infants. *Indian Pediatr. 2010;47 (2):139-43.*
6. World Health Organisation. New World Health Organisation recommendations for care of preterm or low birth weight infants: health policy. *eClinical Medicine. 2023;63:102155.*
7. Kurt A, Ulusoy CO, Kurt DS, Özkan S, Dereli ML, Kından A, et al. Impact of antenatal corticosteroid therapy on neonatal respiratory outcomes in late preterm births. *BMC Pediatr. 2025;25(1):595.*
8. Nahimana E, Ngendahayo M, Magge H, Odhiambo J, Amoroso CL, Muhirwa E, et al. Bubble CPAP to support preterm infants in rural Rwanda: a retrospective cohort study. *BMC Pediatr. 2015;15:135.*
9. Greenough A, Milner AD. The neonatal lung – Physiology and ventilation. Early Human Development . 2025;89 (11):769-774
10. Sujakhu E, Agarwal A, Anbalagan S. Bubble CPAP in infants. In: StatPearls . Treasure Island (FL): StatPearls Publishing; 2025
11. Martin RJ, Nearman HS, Katona PG, Klaus MH. The effect of a low continuous positive airway pressure on the reflex control of respiration in the preterm infant. *J Pediatr. 1977;90(6):976-81.*

12. Manandhar SR. Outcome of Respiratory Distress in Neonates with Bubble CPAP at Neonatal Intensive Care Unit of a Tertiary Hospital. *JNMA J Nepal Med Assoc. 2019;57 (216):92-7.*
13. Qin F, Dong C, Qiu J, Song Q, Konomanyi K, Sesay LSF, et al.
The practice of a modified bubble CPAP therapy in a rural Sierra Leone SCBU-A pilot study. Front Pediatr .2025;13
14. Al-Lawama M, Alkhatib H, Wakileh Z, Elqaisi R, AlMassad G, Badran E, et al.
Bubble CPAP therapy for neonatal respiratory distress in a level III neonatal unit in Amman, Jordan: a prospective observational study. *Int J Gen Med. 2018 Dec 24;12:25-30.*
15. Kawaza K, Machen HE, Brown J, Mwanza Z, Iniguez S, Gest A, et al.
Efficacy of a low-cost bubble CPAP system in treatment of respiratory distress in a neonatal ward in Malawi. PloS One. 2014;9(1):e86327.
16. Chisti MJ, Salam MA, Smith JH, Ahmed T, Pietroni MAC, Shahunja KM, et al.
Bubble continuous positive airway pressure for children with severe pneumonia and hypoxaemia in Bangladesh: an open, randomised controlled trial.
Lancet Lond Engl. 12 sept 2015;386(9998):1057-65.
17. Bradley E, Blencowe H, Moller AB, Okwaraji YB, Sadler F, Gruending A, et al.
Born too soon: global epidemiology of preterm birth and drivers for change.
Reprod Health. 2025;22 (2):105.