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Continuous Positive Airway Pressure versus Conventional Oxygen Therapy in the Management of Severe Bronchiolitis in Infants in Brazzaville

Judicaël Kambourou[1,2*], Darcela Thyerice Ongagna Ayet[2], Aymar Pierre Gildas Oko[1,2], Gothar Regis Bopaka[1,3], Guenol Okoko Okombi[2], Linda Ngamo Tchidjo[2], Léticia Lombet[2], Engoba Moyen[1,2], Georges Marius Moyen[1,2]

[1]Faculty of Health Sciences, Marien Ngouabi University, Brazzaville, Republic of the Congo
[2]Pediatric Intensive Care Unit, Brazzaville University Hospital, Brazzaville, Republic of the Congo
[3]Pulmonology Department, Brazzaville University Hospital, Brazzaville, Republic of the Congo
Email: *judycokam@yahoo.fr

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Abstract

Introduction: Severe bronchiolitis is a major public health issue that poses challenges for healthcare in developing countries. The aim of this study was to compare the effectiveness of homemade CPAP with that of high-flow oxygen therapy using a mask in the management of severe bronchiolitis in Brazzaville. **Patients and Methods:** A single-blind randomized trial was conducted from October 1, 2023 to November 31, 2024, in three level 3 hospitals in Brazzaville. It involved 120 infants hospitalized for severe acute bronchiolitis. Sociodemographic, clinical, paraclinical, therapeutic, and evolutionary variables collected using a survey form were studied. Excel 2021 and Kobo Collect software were used to process and analyze the data. **Results:** 120 infants with a median age of 3 months [IQR: 2 - 5.75] were included. There were 75 boys and 45 girls (sex ratio = 1.7). Parents had a low socioeconomic status in 59.2% of cases. The peak frequency was noted between December and January. Homemade CPAP was used in 60 infants, with an average positive pressure of 5.4 ± 0.52 cmH_2O, and oxygen therapy was used in 60 others, with an average flow rate of 13.1 liters per minute ± 1 liter. The decrease in respiratory rate was rapid in the homemade CPAP group ($p = 0.025$). SpO_2 normalized in the CPAP group by day 1. The overall outcome was favorable in the homemade CPAP group ($p = 0.027$). **Conclusion:** Homemade CPAP is superior to conventional oxygen therapy in the management of severe bronchiolitis.

Keywords

Severe Bronchiolitis, Artisanal CPAP, Conventional Oxygen Therapy, Brazzaville

1. Introduction

Bronchiolitis is a viral infection of the lower respiratory tract that mainly affects infants during their first 12 months of life, limited to the first two episodes [1]. Respiratory syncytial virus (RSV) is the main pathogen, responsible for approximately 60% to 80% of cases [2]. Recognized as a major public health problem due to its morbidity and increasing incidence each year, bronchiolitis poses challenges for management in both developing and industrialized countries [3]. Globally, it is the leading cause of hospitalization for acute respiratory distress in infants, with nearly 3.2 million admissions per year and approximately 59,600 deaths [4] [5]. In France, it affects 30% of infants each winter, with a mortality rate of 1% [6]. Bronchiolitis is associated with one in 15 deaths in infants under 12 months of age, mainly in developing countries [4]. In Sub-Saharan Africa, it is also a common condition. Its hospital prevalence is 9.4% in Cameroon and 5.33% in Madagascar [7] [8]. In Congo, bronchiolitis is the leading acute lower respiratory infection (ALRI), with a hospital prevalence of 56.5% [9].

The treatment of severe bronchiolitis requires hospitalization in a pediatric intensive care unit with respiratory support, including conventional oxygen therapy or continuous positive airway pressure (CPAP).

Conventional CPAP is a non-invasive ventilation technique that is rapidly developing in the pediatric field [9]. Several studies, including that of Milési, have shown its effectiveness in rapidly reducing respiratory effort in infants with severe bronchiolitis [10].

Countries with limited resources in Asia and Sub-Saharan Africa that do not have equipment for conventional CPAP often resort to the use of homemade CPAP in the treatment of infants with severe bronchiolitis [11]. In Brazzaville, few studies have documented the therapeutic modalities for this condition. The objective of this study was to compare the efficacy of homemade CPAP with that of conventional oxygen therapy using a high-flow mask in the management of severe bronchiolitis in infants in Brazzaville.

2. Patients and Methods

A single-blind, parallel-group, randomized controlled trial was conducted from October 1, 2023, to November 1, 2024, in the pediatric intensive care units (PICUs) of three level 3 hospitals in the health department of the city of Brazzaville: the Brazzaville University Hospital Center (CHU-B), the Blanche Gomez Mother and Child Specialized Hospital (HSMEBG), and the Djiri General Hospital (HGD).

This trial involved two groups of infants who were hospitalized for severe acute bronchiolitis (SAB): the first (group 1) consisted of all infants who received homemade CPAP respiratory support, and the second (group 2) consisted of those who received conventional oxygen therapy with a high-flow mask. The study included infants aged between one and 12 months who were hospitalized in the above-mentioned departments for severe bronchiolitis, with the consent of their parents. The definition of severe bronchiolitis used for this study was that updated by the Haute Autorité de Santé (HAS) in France [12]. The centers were chosen non-probabilistically, as they are the only centers with a pediatric intensive care unit. Infants were recruited consecutively and exhaustively as they were admitted. The number of subjects required for the trial was calculated based on the primary endpoint, which is the length of hospital stay; Kelsey's formula:

$N = \frac{2\delta^2 \left(Z\alpha/2 + Z1-\beta\right)^2}{\Delta^2}$ was used to calculate the sample size. According to the study conducted by INOURI [13], the average length of hospital stay was 7 days for the CPAP group with a standard deviation of 2.26 and 10 days for the control group with a standard deviation of 3.19. We therefore have a standard deviation of 3 in both groups (standard deviation = $\delta = 3 \Rightarrow \delta^2 = 9$ days, $1 - \beta =$ 80%, *i.e.* β: 20%, $Z2\ \beta = 0.842$). Where N1 is the number of subjects required in group 1, N2 is the number of subjects required in group 2, N = N1 = N2, and α is the risk of being wrong in claiming that the treatment works. $Z\alpha/2$: α risk value of 5%, in a two-tailed hypothesis, $Z\alpha = 1.96$, β: risk of being wrong in stating that the treatment does not work. $Z_\beta = \beta$ risk value of 20%, Δ: the expected difference between the two means to be compared, $\Delta = m1 - m2$, δ: common variance. $N_1 = N_2 = \frac{2(3)^2 (1.96 + 0.842)}{3^2} = \frac{18 \times 9}{9} = 19$. The minimum sample size calculated was 19 subjects in each group, but to minimize bias, we recruited 60 infants for each group. The homemade CPAP is a non-industrial device assembled at the patient's bedside using readily available components: an oxygen mask, a plastic mineral water bottle, adhesive tape, an oxygen distribution circuit, an infusion pump, and an oxygen pressure regulator (**Iconography 1** and **Iconography 2**). This device is designed to provide continuous positive pressure (5 to 10 liters) in the airways of patients with respiratory distress in order to recruit the alveoli and promote hematosis. To assemble this device, one end of the oxygen mask is cut off and becomes the expiratory tube, which is immersed in the water bottle at a depth in centimeters equivalent to the continuous positive pressure. The regular presence of bubbles in the bottle is a sign that positive pressure is being created, dilating the alveoli. Another tube placed in the same bottle is used to escape gases.

The clinical evaluation of treatment efficacy was performed using a pre-established and pre-tested questionnaire. This questionnaire was designed based on the modified Wang [14] and modified Wood [15] scores, which are standardized scores used to assess the severity of bronchiolitis and asthma attacks, respectively. This questionnaire consisted of five items, including respiratory rate (RR), heart rate (HR),

pulse oxygen saturation (SaO_2), signs of struggle, and wheezing. Each item was scored from 0 to 3 (Table 1). This score was assessed at 15 minutes, 30 minutes, and 1 hour after treatment, then daily for 3 days. The percentage reduction in signs of severity was assessed using the following formula: [(Score on admission − score after treatment)/Score on admission] × 100. The clinical progression of study participants was classified as follows: good clinical progression (75% < score ≤ 100%), moderate clinical progression (50% < score ≤ 75%), and poor clinical progression (score ≤ 50%).

Table 1. Clinical assessment score.

	0	1	2	3
RR	<30	31- 45	46 - 60	>60
HR	<80	81 - 99	100 - 139	>140; <60
SaO_2 (%)	95	92 - 95	91 - 90	<90 or cyanosis
Signs of struggle	None	Intercostal strain	Sternal and clavicular Severe with fluttering of the traction	Severe with fluttering of the traction nostrils
Wheezing		Audible at the end None of exhalation or on auscultation stethoscope	Audible throughout exhalation or without stethoscope	Audible on inspiration and expiration without a stethoscope

HR: Heart rate; RR: Respiratory rate.

Iconography 1. Materials used in artisanal CPAP.

Iconography 2. Infant from group 1 under homemade CPAP.

2.1. Study Variables

- Sociodemographic: Age (months), sex, origin (home, CSI, base hospital), socio-economic status of parents or guardians (low, medium, high), educational level of parents or guardians (primary, secondary, higher).
- Medical history: Reason for consultation, date of onset and duration of symptoms prior to admission, treatment received prior to hospitalization.
- Neonatal history: Birth term (premature, full-term, post-term), adaptation to extrauterine life (AVEU): good, poor, birth weight (hypotrophy, eutrophy, macrosomia), resuscitation at birth, mechanical ventilation, oxygen therapy, hospitalization in neonatology, respiratory distress.
- Medical history: Vaccinations (up to date, not up to date), feeding method (exclusive breastfeeding, mixed feeding, milk substitutes), previous episodes of bronchiolitis, atopy (eczema, rhinitis), gastroesophageal reflux, atopy in parents, influenza infection, passive smoking.
- Clinics: General signs (consciousness, coloration, temperature; respiratory rate (RR), heart rate (HR), pulse oxygen saturation in ambient air (SaO_2), hydration, and nutritional status); physical signs: signs of respiratory distress (flaring nostrils, intercostal and sub- or suprasternal retractions, xiphoid funneling, thoracoabdominal rocking), pulmonary auscultation (wheezing, crackles, sub-crackles, auscultatory silence), complete clinical examination.
- Paraclinical tests: Chest X-ray (normal, bronchial syndrome, interstitial syndrome, alveolar syndrome), blood count (hemoglobin, white blood cells, leukocyte formula), C-reactive protein.
- Therapeutics: Oxygen therapy with high-flow mask (average flow rate, average duration), homemade CPAP (average positive pressure, average duration), nasopharyngeal disinfection (DRP), antibiotics, hyperhydration, fractional feeding, nebulization, physiotherapy.

- Evolving: Length of hospital stay, progression (favorable, unfavorable), complications (death, recovery, secondary infection).

2.2. Statistical Analysis

The data were entered into a template designed using the Kobo Collect application and hosted on KoboToolbox. Data processing and graphing were performed using Excel. Statistical analyses were performed using SPSS 25 software. Qualitative variables were presented as proportions, while quantitative variables were expressed as means accompanied by their standard deviation, or as medians with their quartiles when the distribution was not proportional. To compare proportions, Pearson's statistical test was used at a significance level of 5%. Fisher's exact test was used when at least one theoretical sample size was less than 5.

2.3. Ethical Considerations

The identity of the infants was anonymous thanks to the coding in the questionnaire. Each parent or guardian of the infants was interviewed individually. The research protocol was submitted to the Health Science Research Ethics Committee (CERSSA) for approval, and ethical clearance was obtained following decision No. 195-24/MESRSIT/DGRST/CERSSA/-24. We declare no conflicts of interest in the conduct of this work.

3. Results

3.1. Descriptive Study

Infant recruitment procedure is shown in Figure 1.

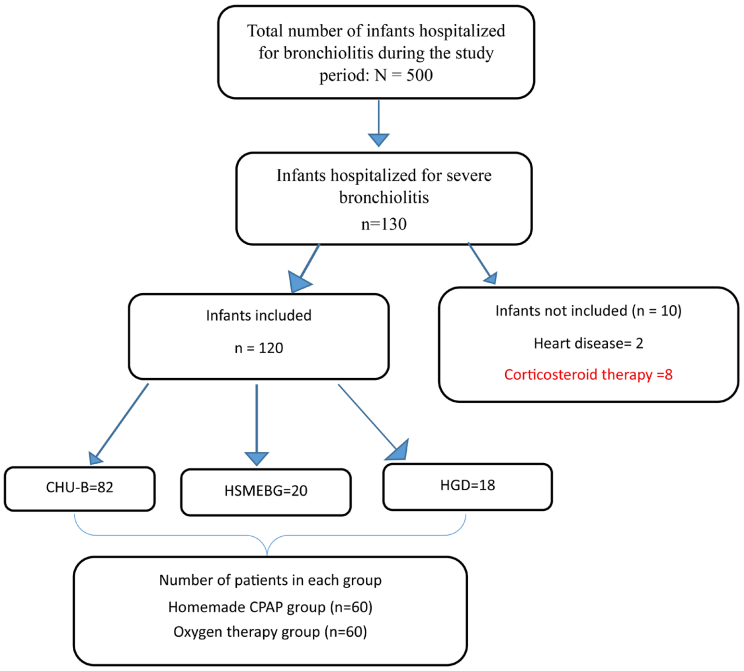

Figure 1. Infant recruitment chart.

3.2. Ociodemographic Characteristics

The median age of infants included in the study was 3 months (range: 2 - 5.75). The age group of 1 to 6 months was the most represented, with 99 cases (82.5%). There were 75 boys (62.5%) and 45 girls (37.5%), giving a *sex ratio* of 1.7. The infants came directly from home in 110 (91.7%) cases and from a health center in 10 (8.3%) cases. The socioeconomic status of their parents or guardians was low in 71 (59.2%) cases, medium in 12 (10%) cases, and high in 37 (30.8%) cases. Fifty-four (45%) parents or guardians of infants had no education; 13 (10.8%) had primary education, and 46 (38.4%) had higher education. The median household size was 5 people (4 - 6), with extremes of 2 and 9 people.

3.3. Infant History

Among the infants included, 9 (7.5%) were born prematurely, of whom 6 (5%) had experienced respiratory distress in the neonatal period and received oxygen therapy. No infants had been resuscitated at birth or mechanically ventilated. The infants were fed a mixed diet in 96 (80%) cases, and a first episode of bronchiolitis was noted in 8 (6.7%) cases. None of the infants had gastroesophageal reflux. Influenza-like illness was found in the household in 62 (51.7%) cases; in 21 (17.1%) cases, they were exposed to secondhand smoke.

3.4. Clinical Aspects

The main reasons for consultation were respiratory distress in 110 (91.7%) cases, cough in 35 (29.2%) cases, and fever in 29 (24.2%) cases. The average time from symptom onset to admission was 4.2 ± 0.2 days (range 2 to 7 days). Infants had received treatment prior to admission in 99 (82.5%) cases. Symptomatic treatment was administered in 117 (97.5%) cases and antibiotic therapy in three (2.5%) cases.

Signs of respiratory distress were present in all infants: nasal flaring in 110 (91.7%) cases, retractions in 98 (81.7%) cases, xiphoid funneling in 43 (35.8%) cases, and thoracoabdominal rocking in 7 (5.8%) cases.

The physical examination noted tachypnea in 118 (98.3%) cases, tachycardia in 47 (39.2%) cases, and desaturation with $SaO_2 < 90\%$ in 103 (85.3%) cases. Pulmonary auscultation mainly revealed wheezing in 95 (79.2%) cases, crackles in 17 (14.2%) cases, and rales in 5 cases.

3.5. Paraclinical Aspects

Radiographic

A chest X-ray was performed on all infants; it was a frontal view. It showed bronchial syndrome in 88 (73.3%) cases, and atelectasis and alveolar syndrome in five cases each.

Biological tests

The biological tests performed on infants were complete blood count and C-reactive protein (CRP). Hyperleukocytosis was noted in 80 patients (66.7%), moderate

anemia in 14 (11.7%) infants, and elevated CRP in three infants.

3.6. Therapeutic Parameters

Respiratory support

The homemade CPAP was used for infants in group 1, and the interface used was a nasal cannula. The average continuous positive pressure was 5.4 ± 0.52 cmH2O (range 5 to 8 cmH_2O); the average duration was 2.4 ± 0.9 (range 1 to 4 days). The fluid used was mineral water.

High-flow oxygen therapy was administered to infants in group 2; the average flow rate was 13.1 ± 1 liters per minute. The average duration of oxygen therapy was 3.3 ± 1 days (range 2 to 6 days).

3.7. Other Treatments

Nasopharyngeal disinfection (NPD) with saline solution and hyperhydration were performed in all infants. The solutions used were IV fluids combined with electrolytes (NaCl, KCl, Gluca) and/or 0.9% isotonic saline solution (SSI: 0.9%) in cases of dehydration. Antibiotic therapy was administered to 9 infants (7.5%). The antibiotics administered were ceftriaxone in 5 cases, and amoxicillin and amoxicillin-clavulanic acid in 2 cases each.

3.8. Progression

The progression was favorable for 109 (90.8%) infants and unfavorable for 11 (9.2%). In the group of infants who received homemade CPAP, the progression was favorable in 58 infants (96.7%). Their average length of hospital stay was 3.2 ± 1.1 days, ranging from 2 to 5 days. Bacterial superinfection was noted in two cases. In the group of infants who received high-flow oxygen therapy via a mask, favorable outcomes were noted in 51 (85%) cases, with an average hospital stay of 4.3 ± 1.4 days, ranging from 2 to 7 days. Seven infants (11.7%) developed bacterial superinfection and two (3.3%) died.

3.9. Analytical Study

Signs of respiratory distress

Among patients who had a good outcome (n = 109), in the homemade CPAP group, the average time required for the disappearance of signs of respiratory distress was 46 ± 5.20 hours vs. 56.92 ± 8.37 hours in the conventional oxygen therapy group ($p < 0.001$).

Respiratory rate (RR) and pulse oxygen saturation (SpO_2)

The decrease in RR on day 1 of treatment was on average 40.2 ± 4 cycles per minute for the oxygen therapy group and 35.1 ± 2 cycles per minute for the CPAP group ($p = 0.025$). From the first day of treatment, SaO_2 averaged 94.8% ± 2.7% for the CPAP group and 92.6% ± 3% for the oxygen therapy group ($p = 0.000$) (**Figure 2** and **Figure 3**).

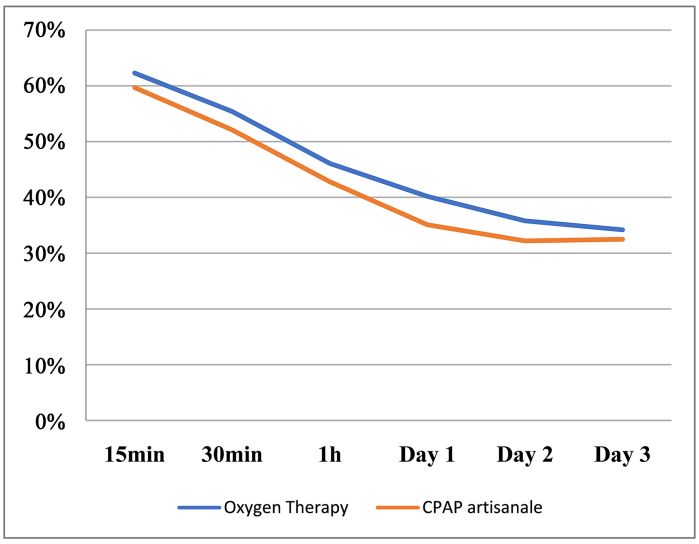

Figure 2. Changes in respiratory rate in infants in both groups.

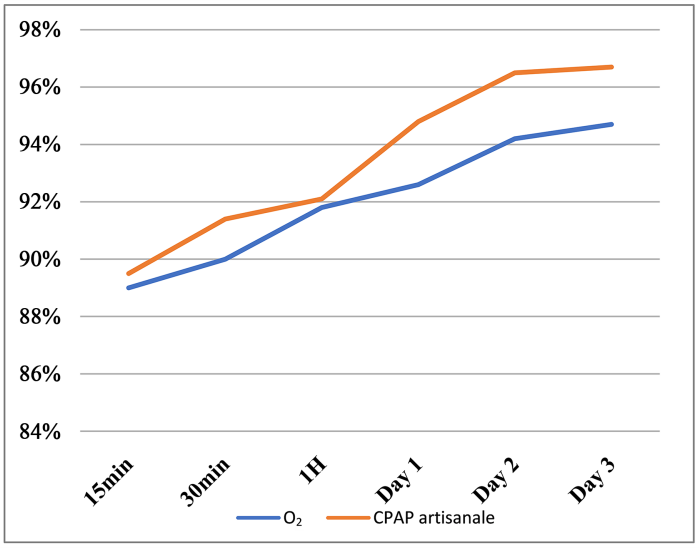

Figure 3. SaO_2 changes in both groups.

3.10. Reduction in Oxygen Requirements

The reduction in oxygen requirements was significant from the first day of treatment in the CPAP group ($p < 0.05$) (Table 2).

Table 2. Comparison of the percentage reduction in oxygen requirements during treatment in the two groups.

	O_2	CPAP	p
	n (%)	n (%)	
Reduction to 15 min			0.752
≤50%	54 (90)	55 (91.7)	
50% - 75%	6 (10)	5 (8.3)	

Continued

Reduction to 30 min			0.752
≤50%	54 (90)	55 (91.7)	
50% - 75%	6 (10)	5 (8.3)	
Réduction to 1 hour			0.598
≤50%	42 (70)	37 (61.7)	
50% - 75%	15 (25)	20 (33.3)	
>75%	3 (5)	3 (5)	
Reduction to day 1			0.027*
≤50%	28 (46.7)	14 (23.3)	
50% - 75%	12 (20)	16 (26.7)	
>75%	20 (33.3)	30 (50)	
Reduction to day 2			0.009*
≤50%	6 (10.0)	5 (8.3)	
50% - 75%	28 (46.7)	13 (21.7)	
>75%	26 (43.3)	42 (70)	
Reduction to day 3			0.211
≤50%	6 (10.9)	3 (7.3)	
50% - 75%	27 (49.1)	14 (34.1)	
>75%	22 (40)	24 (58.5)	

*$p < 0.05$, statistically significant difference.

3.11. Outcome

Under treatment, the outcome was more favorable in group 1 (CPAP) than in group 2 (oxygen therapy with high-flow mask), $p = 0.02$.

The average length of hospital stay was 4.3 ± 1.4 days in the oxygen therapy group and 3.2 ± 1.2 days in the homemade CPAP group. There was a statistically significant difference between the two groups ($p = 0.000$).

In our sample, there was no significant difference between the two groups ($p \geq 0.05$) in terms of the occurrence of complications.

4. Discussion

This multicenter study was a randomized, parallel-group, single-blind clinical trial. Its aim was to contribute to improving the management of severe bronchiolitis in infants hospitalized in pediatric wards in Brazzaville. The choice of study type focused on innovation in the therapeutic approach, as it was based on a rigorous method that minimizes bias and ensures the comparability of results at a lower cost. However, the study encountered certain difficulties, including the practical variability of homemade CPAP devices and the limited technical capabilities that prevented certain biological tests, such as blood gas and blood ionogram tests, from being performed. The evolution of certain parameters could not be evaluated during treatment.

In Brazzaville, severe bronchiolitis is most common in infants under 6 months of age, as evidenced by the median age of infants in this study, which is 3 months [IQR: 2 - 5.75]. The work of Tsifiregna *et al.* in Madagascar found that 66.7% of bronchiolitis cases occurred in infants under 6 months of age [8]. The young age of the infant is recognized as a factor in the severity of bronchiolitis [16]. Severe bronchiolitis affects boys (62.5%) more than girls, with a sex ratio of 1.8 in our population. This result is comparable to that reported by Ouologuem in Bamako [17]. The predominance of males in bronchiolitis is thought to be related to the narrowness of the bronchi in young boys [18].

CPAP has become an increasingly popular treatment for bronchiolitis in recent years due to its advantages over conventional oxygen therapy. Homemade CPAP is an equally effective alternative for the treatment of severe bronchiolitis in low-income countries, as shown by the results of this study. Homemade CPAP improved the signs of respiratory distress in infants more quickly than conventional oxygen therapy, with a statistically significant difference ($p < 0.001$). These results are similar to those of Essouri *et al.*'s study, which reported a significant reduction in respiratory effort in infants receiving CPAP within a median time of 48 hours [19]. According to Ganu *et al.* in India, CPAP significantly reduces the duration of respiratory distress and improves respiratory efficiency compared to conventional oxygen therapy [20]. These results are attributed to the airway-stabilizing effect and reduction in alveolar collapse induced by CPAP.

The homemade CPAP device led to a reduction in respiratory rate from the first day of treatment. Our results are similar to those of studies by Kamal *et al.* and Dayan *et al.* [21] [22], who observed a significant decrease in respiratory rate between the two groups in favor of CPAP. However, Mélési *et al.* [10] and Thia *et al.* [23] did not find a significant change in respiratory rate. Differences in treatment protocols, characteristics of the study populations, or measurement criteria used could explain this disparity. Improvement in pulse oxygen saturation (SpO_2) was greater in the homemade CPAP group than in the conventional oxygen therapy group from the first day of treatment ($p = 0.000$). These results are consistent with those of Dayan *et al.* [22] and Karmal *et al.* [21], who also observed a significant difference. The improvement in oxygenation is due to the opening of the airways, under the effect of the positive pressure support provided by the homemade CPAP, which improves the ventilation-perfusion mismatch, a key element in the pathophysiology of bronchiolitis. In addition, the reduction in respiratory effort allows for good oxygenation. Oxygen requirements are therefore improved more quickly (from the first hour) in the CPAP group.

In this study, we noted that the risk of bacterial superinfection was lower in the homemade CPAP group than in the conventional oxygen therapy group (2.3% vs. 11.6%), although the difference was not statistically significant. Inouri's 2021 study reported a statistically significant difference in the occurrence of superinfection between the two groups [13]. The short length of hospital stay for infants in the CPAP group would certainly minimize the risk of bacterial superinfection. The low over-

all mortality rate of bronchiolitis (1.6%) in this study is similar to that reported by Inouri [13] and Che *et al.* [24]. According to these authors, deaths occurred mainly in the conventional oxygen therapy group, as in our case. The two deaths in this study occurred in the context of acute respiratory distress syndrome (ARDS). Hammer, in a study on RSV-related deaths, also reported only one death among 37 infants included in the study.

Homemade CPAP is an effective therapeutic method that reduces the length of hospital stay for infants with severe bronchiolitis compared to oxygen (3.2 ± 1.1 days vs. 4.3 ± 1.7 days) ($p = 0.000$); this finding is identical to that reported by Pierre *et al.* [25]. Early introduction of non-invasive ventilation, such as homemade CPAP, reduces the length of hospital stays and the occurrence of associated complications.

5. Conclusion

Bronchiolitis is a public health issue. In Brazzaville, it mainly affects male infants under 6 months of age from low socioeconomic backgrounds. Homemade CPAP seems to be a promising alternative for treating severe bronchiolitis in our resource-limited setting. It allows for rapid improvement in the respiratory status of infants and normalization of pulse oxygen saturation. In addition, it reduces the length of hospitalization, the occurrence of complications, and the number of deaths. Further, larger-scale studies appear to be necessary to refine treatment protocols and ensure the safety of its long-term use.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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