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ORIGINAL ARTICLE

Hood versus mask nebulization in infants with evolving bronchopulmonary dysplasia in the neonatal intensive care unit

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Objective: To compare infants' discomfort, nursing-time and caregiver preference, and assess the clinical efficiency (as a secondary outcome) of hood versus facemask nebulization in infants with evolving bronchopulmonary dysplasia (BPD) in the neonatal intensive care unit.

Study Design: A prospective, open, randomized, controlled crossover clinical trial. In total, 10 infants with BPD who were on inhaled beta-agonist bronchodilators and corticosteroids were randomly assigned to receive their nebulized treatments either by a facemask, or by a hood for 2–3 days, and then crossover to receive the same treatments with the other technique for another 2–3 days. Infants' discomfort, nursing-time, caregiver preference and clinical efficiency were compared.

Results: At baseline there was no significant clinical difference between the groups. Nurse-time required for administering the hood nebulization (mean ± s.e.m.: 1.9 ± 0.1 min) was significantly shorter than the time for mask nebulization (12.0 ± 0.6 min, $P<0.0001$). Infants' discomfort score was significantly lower (0.1 ± 0.04) for hood versus mask nebulization (2.5 ± 0.2, $P<0.0001$). Nurses and parents unequivocally preferred the hood treatment. During both mask and hood nebulization therapies (2–3 days) clinical efficiency was comparable. While both methods caused an immediate (20 min post) clinical improvement, the immediate respiratory assessment change score was significantly greater for the hood versus the mask nebulization (0.62 ± 0.27 versus 0.13 ± 0.14, $P<0.05$).

Conclusions: Nebulization of aerosolized medications in infants with evolving BPD by hood was less time-consuming for caregivers and was much better tolerated by the infants while being at least as effective as the conventional facemask nebulization.

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Introduction

Aerosol medications are commonly used in infants with bronchopulmonary dysplasia (BPD).[1,2] Most devices for administering aerosol medications to infants and neonates are derived from those developed initially for delivery of asthma medications to adults and older children. Most of these devices were modified for use by infants simply by adding a small facemask covering the mouth and nose, which provides the interface between aerosol generator and patient. For optimum therapy, the edge of the mask must fit tightly to the infant's face, and that may agitate the infant.[3] It has been shown that with jet nebulization even a one cm gap between the mask and the face reduces the dose delivered by 50%.[4] The current practice in most Neonatal Intensive Care Units (NICU) requires that the nurse will open the incubator, hold the baby in a semiseated position and attach the mask to the infant's face, during the entire nebulization period (Figure 1). This is an elaborate and time-consuming task for a busy nurse in the NICU. Thus, there is clearly a need to develop a more acceptable and patient friendly interfaces for improving aerosol delivery to infants.[5,6]

As no facemask is required and nothing touches the face, a hood interface should provide a logical and compelling, infant friendly alternative for delivering nebulized drugs to infants. Furthermore, oxygen is routinely given via hood to infants in the NICU. Amirav *et al*.[7] recently demonstrated scintigraphically that inhalation via hood in wheezy infants achieved a comparable lung deposition of salbutamol to that of a conventional facemask.

We hypothesized that hood and mask nebulization would provide a comparable clinical response, but that the hood would be less time-consuming and better tolerated by the infants. The present study was designed to evaluate infants' discomfort, nursing-time and caregiver preference, and the clinical efficiency of hood versus facemask nebulization of aerosolized medications in infants with evolving BPD in the NICU.

Subjects and methods

Design

This study was a prospective, open, randomized controlled crossover clinical trial comparing treatment convenience for the

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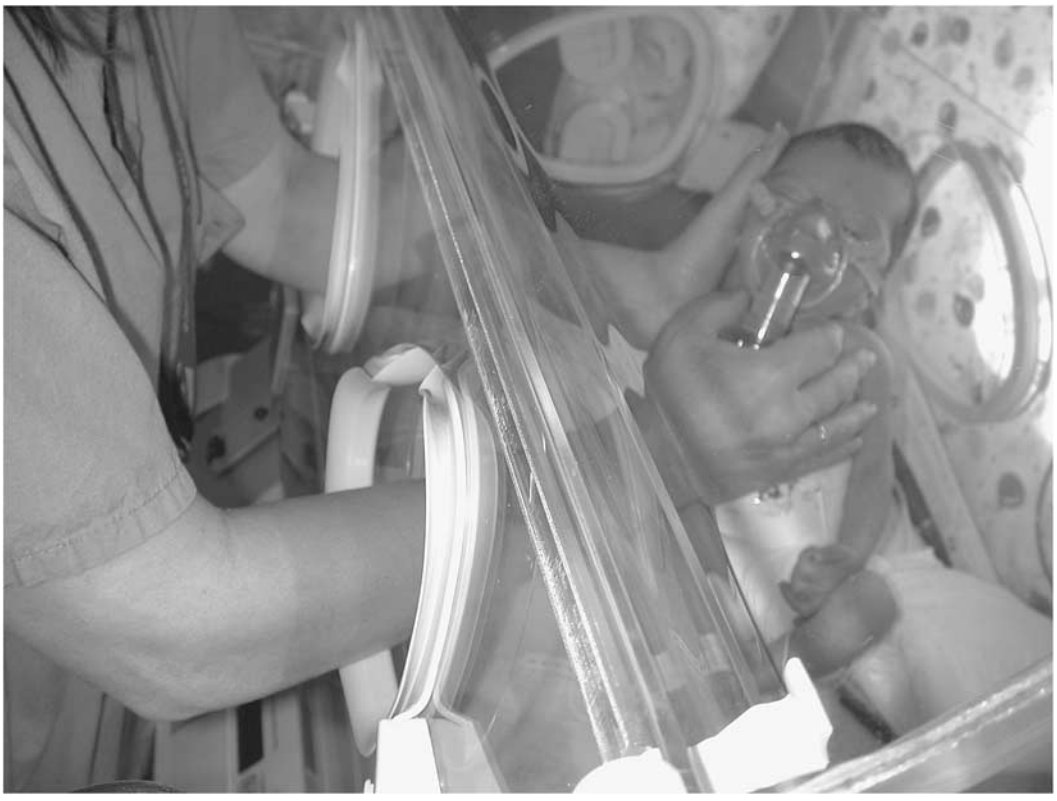

Figure 1 Mask nebulisation, with nurses' 'hands-on' the baby, in the incubator.

infant and the nurse and clinical outcomes of hood versus facemask nebulization of beta-agonist bronchodilators and inhaled corticosteroids (ICS) in infants with evolving BPD.

Infants were randomly assigned to receive the first treatment either by a jet nebulizer (Opti-Mist Nebulizer, Maersk Medical SA, Reynosa, Mexico) with a facemask, or by a hood (Child-Hood, Baby's Breath Ltd, Advanced Inhalation Technologies, Or-Akiva, Israel) for a course of 2–3 days followed by 2–3 days of nebulization therapy with the other aerosol delivery system.

Patients

Spontaneously breathing premature infants with evolving BPD whose attending physician decided to treat them with inhaled beta-agonist bronchodilators or ICS were eligible to participate in the study. Infants were recruited consecutively over a 12-month period. BPD was diagnosed when the premature infants required oxygen to achieve an oxygen saturation >92% at 36 weeks postconceptional age with compatible chest radiograph.[8] The parents of all infants signed a written informed consent form. The study was approved by the Ethics Committee of Bnai-Zion Medical Center. Infants were excluded from the study if they had cardiac disease or if they were clinically unstable.

Treatments

For the facemask treatments, infants were held by the nurse in a semiseated position with the neck slightly extended in the crib or incubator, and the mask was held firmly against the infant's face (Figure 1). The hood used a jet-inverted nebulizer and treatments were administered in an incubator or crib (Figure 2). All aerosol treatments were administered with the infants calm or asleep and on their back after a feeding.

Medications

Nebulization treatments were assigned by the attending neonatologist. Beta agonist, Terbutaline Sulfate (Teva Pharm. Ind. Ltd, Petach-Tikva, Israel) respirator solution (1 ml = 10 mg), was inhaled three times a day. The nebulizer was charged with a dose of 2 mg (0.2 ml) in 2 ml of normal saline. ICS, Budesonide respules (Teva Pharm. Ind. Ltd, Petach-Tikva, Israel), 0.5 ml, suspension for inhalation (2 ml = 1 mg) was added to the morning and evening inhalations. The nebulizers were operated by an oxygen cylinder at a flow rate of 5 l/min until the drug-solution was administered as indicated by nebulizer sputtering.

Primary outcome measures

1. Discomfort score: infants were observed every minute during each nebulization by the nurses. One point was scored for every minute that the infant either cried or resisted the treatment for more than 20 s; a maximal score of 6 represented maximal distress, whereas 0 represented no distress.[7]

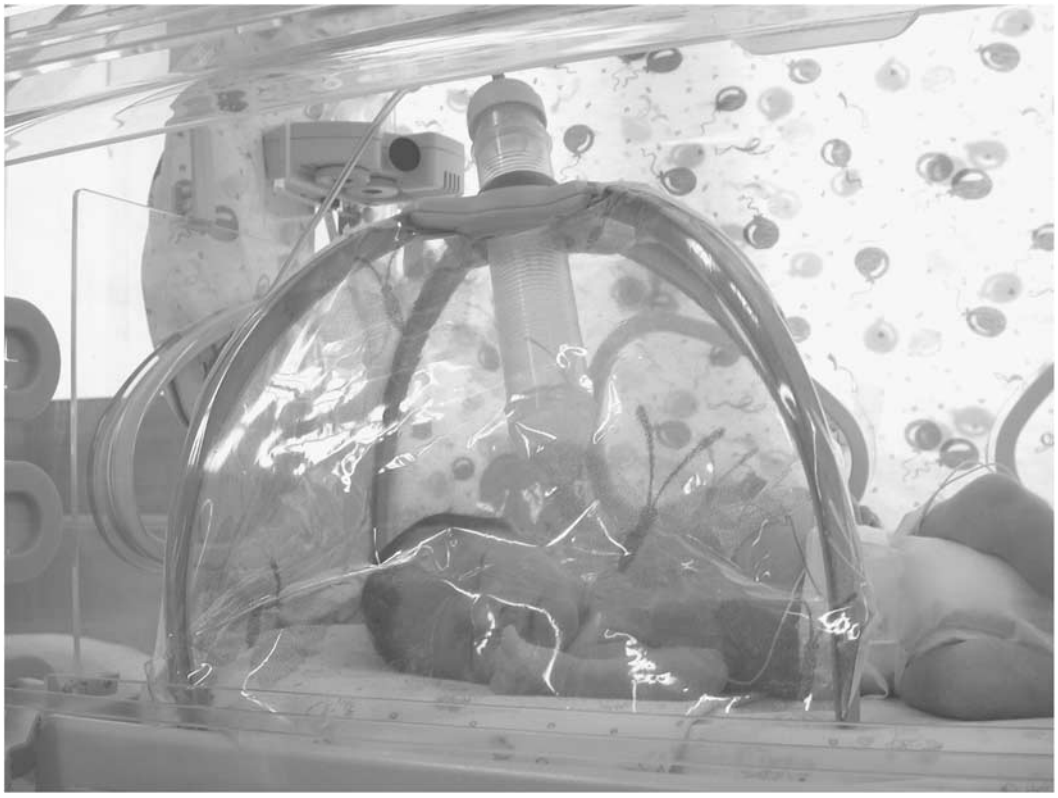

Figure 2 Hood nebulisation in the incubator.

2. Nurse-time: the specific time that the nurse was directly occupied in preparing and administering the nebulization was measured by a stopwatch operated by the nurse.
3. Nurse/parent preference: nurses and parents were asked by a written questionnaire if they had a preference, or no preference, for either delivery method. This question was asked at the end of the study.

Secondary outcome measures

1. Clinical observations: Vital signs including respiratory rate, heart rate, blood pressure, pulse oximetry oxygen saturation and oxygen requirements were recorded. All physical examinations were performed by a senior neonatologist. A simple and objective validated score (respiratory distress assessment instrument (RDAI)) was used to score retractions and wheeze: 0 for no wheeze or retractions; 1 for mild or 'present' wheeze or retraction; and 3 for moderate to severe wheeze or retractions. The RDAI is the sum of the points given for retraction and wheezing scores. This score was chosen since these variables were found to be reliable for evaluating wheezing infants[9–11] and was adjusted for small premature infants. The change in respiratory status before and after inhalation and at the start and at the end of the 2–3 day course of nebulization therapy was based on a composite measure termed respiratory assessment change score (RACS).[9,10] This measure combines differences of RDAI and respiratory rate. Respiratory rate difference was calculated by scoring 1 point for each five breaths difference (0 points scored for a change smaller than five breaths).
   To assess the effect of the 2–3 day course (mask or hood nebulization three times a day) data were recorded on the mornings before, and at the end of the course of each mode of nebulization. The immediate short-term effect was evaluated once daily, before and 20 min after the morning inhalation.

Statistical analysis

Sample size calculations were based on previous data in infants receiving bronchodilator treatment via conventional nebulizers for BPD.[6] Based on these data we estimated that there would be a more than 80% chance of detecting a 50% difference between the groups (alpha = 0.05) when sample size (n) is 10 patients for each mode of treatment.

Paired t test, two-sided, was used to compare the two modes of nebulization before and after each treatment and before and after each course of therapy. The unpaired t test was used for evaluating the RACS score between both techniques. The Mann–Whitney U test and the Wilcoxon Rank Sum test were used as appropriate

when selecting a nonparametric test. Data are presented as mean ± standard error of the mean (s.e.m.). Significance was set at $P<0.05$.

Results

In total, 10 clinically stable infants with evolving BPD (six males, four females) participated in the study. Their mean birth weight was 898 ± 56 g, gestational age was 26.9 ± 0.4 weeks, study weight was 1986 ± 247 g, study age was 66 ± 8 days, and postconceptional age was 35.9 ± 1.2 weeks. Apart from inhaled beta-agonist bronchodilators and ICS, four infants received caffeine for apnea of prematurity and seven received diuretics (hydrochlorothiazides and spironolactone) for BPD during the study.

Five infants started with hood and five with mask nebulization in random order. There was no significant clinical difference between the groups at the start of each course of therapy with either mode of nebulization (Table 1).

Nursing time required for treatment administration was significantly shorter (1.9 ± 0.1 versus 12.0 ± 0.6 min, $P<0.0001$) and discomfort score was significantly lower (0.1 ± 0.04 versus 2.5 ± 0.2, $P<0.0001$) for hood versus mask nebulization. All of the nurses (24) and 7/7 parents voted for the hood as their preferred mode of nebulization when taking into account overall convenience and the infants' apparent comfort during therapy (three parents did not have any preference as they were not involved in the therapy in the nursery).

While during mask nebulization there was no significant change in RDAI, during hood nebulization the RDAI improved significantly (Table 2). RACS from the start to the end of the nebulization course was comparable with both nebulization techniques (Table 3).

The immediate (20 min) clinical response to mask nebulization was increased heart rate and improved RDAI (Table 4). Hood nebulization resulted in a marked and less variable immediate improvement in clinical respiratory variables (Table 4), which was significantly greater than the response to mask nebulization (Table 5).

Table 1 Baseline clinical status prior to nebulization course

	Mask (n = 10)	*Hood* (n = 10)	P
Respiratory rate (breath/min)	57 ± 5	58 ± 6	NS
Heart rate (beats/min)	155 ± 5	158 ± 4	NS
Mean blood pressure (mmHg)	55 ± 3	53 ± 2	NS
FiO_2	0.28 ± 0.02	0.24 ± 0.04	NS
SpO_2	97 ± 0.8	97 ± 0.7	NS
Retraction score	0.6 ± 0.2	0.7 ± 0.3	NS
Wheeze score	0.2 ± 0.1	0.3 ± 0.1	NS
RDAI	0.4 ± 0.1	0.5 ± 0.2	NS

FiO_2 = fractional inspired oxygen concentration; SpO_2 = pulse oximetry oxygen saturation (%); RDAI = respiratory distress assessment instrument; NS = not significant.

Table 2 Clinical status prior to and at the end of the nebulization course (2–3 days)

	Hood (n = 10)			*Mask* (n = 10)		
	Pre	*Post*	P<	*Pre*	*Post*	P<
RR	57 ± 6	60 ± 4	NS	57 ± 5	56 ± 5	NS
HR	158 ± 4	154 ± 4	NS	155 ± 5	159 ± 4	NS
BP	53 ± 2	53 ± 3	NS	55 ± 3	54 ± 2	NS
FiO_2	0.23 ± 0.04	0.21 ± 0.02	NS	0.28 ± 0.02	0.28 ± 0.02	NS
SpO_2	97 ± 0.7	97 ± 0.6	NS	97 ± 0.8	97 ± 0.9	NS
RS	0.7 ± 0.3	0.2 ± 0.1	0.052	0.6 ± 0.2	0.5 ± 0.2	NS
WS	0.3 ± 0.1	0.0 ± 0.0	NS	0.2 ± 0.1	0.1 ± 0.1	NS
RDAI	0.5 ± 0.2	0.1 ± 0.1	0.01	0.4 ± 0.1	0.3 ± 0.1	NS

RR = respiratory rate (breaths per minutes); HR = heart rate (beats per minute); BP = mean blood pressure (mmHg); FiO_2 = fractional inspired oxygen concentration; SpO_2 = oxygen pulse oximetry (%); RS = retraction score; WS = wheezing score; RDAI = respiratory distress assessment instrument; NS = not significant.

Table 3 Comparision of the change in clinical status from start to the end of the nebulization course (2–3 days) between hood and mask nebulization

	Hood (n = 10)	*Mask* (n = 10)	P
RR change	−0.30 ± 1.06	0.30 ± 1.19	NS
RS change	0.50 ± 0.22	0.10 ± 0.10	NS
WS change	0.30 ± 0.15	0.10 ± 0.17	NS
RACS	0.17 ± 0.35	0.17 ± 0.38	NS

RR = respiratory rate (breaths per minutes); RS = retraction score; WS = wheezing score; RACS = respiratory assessment change score; NS = not significant.

Table 4 Clinical status pre- and 20 min post nebulization

	Hood (n = 25)			*Mask* (n = 25)		
	Pre	*Post*	P<	*Pre*	*Post*	P<
RR	57 ± 4	51 ± 4	NS	59 ± 3	58 ± 4	NS
HR	157 ± 3	160 ± 2	NS	154 ± 2	162 ± 3	0.05
BP	54 ± 2	55 ± 2	NS	54 ± 2	53 ± 2	NS
FiO_2	0.28 ± 0.02	0.27 ± 0.01	NS	0.26 ± 0.01	0.26 ± 0.01	NS
SpO_2	93 ± 4	92 ± 4	NS	92 ± 4	92 ± 4	NS
RS	0.8 ± 0.2	0.5 ± 0.1	0.05	0.4 ± 0.1	0.2 ± 0.1	NS
WS	0.44 ± 0.1	0.04 ± 0.04	0.005	0.2 ± 0.1	0.08 ± 0.05	NS
RDAI	0.62 ± 0.1	0.24 ± 0.1	0.0005	0.30 ± 0.06	0.16 ± 0.05	0.05

RR = respiratory rate (breaths per minutes); HR = heart rate (beats per minute); BP = mean blood pressure (mmHg); FiO_2 = fractional inspired oxygen concentration; SpO_2 = oxygen pulse oximetry (%); RS = retraction score; WS = wheezing score; RDAI = respiratory distress assessment instrument; NS = not significant.

Table 5 Comparison of the change in clinical status pre- and 20 min post nebulization between hood and mask nebulization

	Hood (n = 25)	*Mask* (n = 25)	P
RR change	1.12 ± 0.78	0.12 ± 0.40	0.09
RS change	0.36 ± 0.15	0.16 ± 0.09	NS
WS change	0.40 ± 0.11	0.12 ± 0.08	0.05
RACS	0.62 ± 0.27	0.13 ± 0.14	< 0.05

RR = respiratory rate (breaths per minutes); RS = retraction score; WS = wheezing score; RACS = respiratory assesment change score; NS = not significant.

Discussion

This is the first reported trial of hood nebulization in the NICU. Our pilot study showed that nebulization of aerosolized medications in infants with evolving BPD by hood was less time-consuming for caregivers and was much better tolerated by the infants while being at least as effective as the conventional facemask nebulization.

We are aware that the effectiveness of beta-agonist bronchodilators and ICS in the treatment of premature infants with evolving BPD is much debated.[1,2,8] Furthermore, the use of inhaled steroids is limited according to the new guidelines of the American Academy of Pediatrics.[12] Our study was not designed to address the rationale for and effectiveness of these medications. However, since aerosol therapies are nevertheless used in many NICUs, we primarily focused on infants' discomfort and the time spent by nurses during both modes of aerosol therapy. At the same time, and as a secondary outcome, we undertook clinical measurements to evaluate the relative effectiveness of the two methods of nebulization.

The primary goal of our study was to compare the hood versus mask aerosol administration in terms of infants' discomfort and nursing-time. It is known that achieving a good facemask seal may be difficult in many infants due to agitation and crying.[3] Furthermore, nebulizer treatments take about 10 to 15 min and since this is longer than most infants will tolerate, they become impatient and agitated while using a mask. In our study, the focus was not on the nebulization time itself, but on the time required by the nurse to administer the treatments. That time was significantly shorter with the hood compared to a mask. This difference was simply due to the fact that the nurse was not required to hold the mask during the entire nebulization time in order to ensure a good seal with the infant's face, or to keep the infant in a semisitting position. The infant's discomfort score was significantly lower during hood versus mask treatment. Similar findings of better tolerability were reported in wheezy infants.[7] After mask nebulization, heart rate increased significantly (Table 4). This could suggest a more significant systemic effect, but as all the other measures remained stable, the more plausible explanation is that it is another reflection of irritation and discomfort related to the facemask application. Irritation and agitation could greatly reduce the drug delivery to the infant's lungs and reduce treatment efficiency.[7,13,14] This could explain in part our findings of some clinical advantage of hood versus mask nebulization. Infant's comfort plays an important role in growing premies. All efforts should be made to decrease discomfort and stress. Avoiding stress by using a more infant friendly nebulization technique may be beneficial. Although subjective, all the nurses and caregiver parents unequivocally, chose the hood as their preferred mode of nebulization when taking into account their convenience and the infant's comfort during therapy.

The study period spanned 50 days (2.5 days for each infant, times 10 infants, times two for crossover). Each treatment with the hood saved ~10 min of nursing time. A simple calculation of the total time saved for the nurses during the study (10 min, times three daily inhalations, times 50 days) amounts to 1500 min or 25 h. In these days with a shortage of intensive care staff, a limited budget and crowded nurseries this time saving would be of considerable importance.

Overall, both methods had comparable clinical efficiency, with advantage to hood nebulization in the short-term effects. The short-term (20 min) postinhalation effect was similar in terms of no change in oxygen saturation and oxygen requirements (Table 4). However, while both modes of therapy resulted in significant improvement in RDAI, this improvement was more consistent and significantly larger with the hood as compared to mask nebulization (Tables 4 and 5). At the end of the 2–3 days course of the treatment (intermediate-term), the clinical status of the infants remained unchanged with both techniques in terms of oxygen saturation and oxygen requirements (Table 2). At the end of the hood nebulization course the infants showed improvement in physical examination as reflected in the RDAIs. Yet, there was no significant difference between the nebulization techniques when comparing the changes in the respiratory parameters (RACS) in the intermediate term (Table 3). Our results are in accordance with the study of Amirav *et al*.[7] in 14 infants with mean age of 8 months, where lung deposition of hood and mask nebulization were comparable, and both treatments provided similar clinical benefits and side effects. We did not observe changes in oxygen saturation and oxygen requirements, and this may be related to our population that had only mild BPD, and was relatively stable, or to the effectiveness of the treatment that is debatable in infants with BPD. In contrast to our study, Amirav *et al*.[7] in a different population of wheezy infants, showed improved oxygen saturation, reduced respiratory rate and increased heart rate with both techniques.

Although there is a tendency to move away from nebulizers towards smaller pressurized metered dose inhalers (MDI) with holding chambers,[8,15–17] these also require a tightly fitting facemask interface, with all the problems noted above except for a

considerable reduction in the time required to complete aerosol administration. Furthermore, it is still questionable if very small preemies can effectively open the inspiratory valve when using commerical valved spacers with MDIs and under these conditions it may be better to remove the valves altogether.[18] In future studies, hood nebulization should be compared to MDIs and aerosol holding chambers with mask in these infants.

The limitation of the present pilot study is that it was an open study (it is impossible to do a blinded study for the primary outcome measure when comparing these two nebulization techniques). All clinical observations were made by a single observer, thus interobserver variations were avoided. However, a single observer assessment in itself could be a source of a bias in the clinical observations. Thus, we should be cautious in the interpretation of the clinical advantages of the hood (the clinical efficiency was only the secondary outcome measure in our study and we concluded that both methods had overall comparable clinical efficiency despite some advantages of the hood that included objective parameters).

We conclude that nebulization of aerosolized medications in infants with evolving BPD by hood was less time-consuming for caregivers and was much better tolerated by the infants while being at least as effective as the conventional facemask nebulization. In the settings of NICU, these advantages are of considerable importance and indicate greater cost effectiveness.

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