



Comparison of methods of bag and mask ventilation for neonatal resuscitation

Neil N. Finer^{a,*}, Wade Rich^a, Alissa Craft^b, Christopher Henderson^a

^a Division of Neonatology, Department of Pediatrics, San Diego Medical Center, University of California, 200 West Arbor Drive, 8774, San Diego, CA 92103-8774, USA

^b Neonatal Specialists Ltd., 1111 E. McDowell, Phoenix, AZ 85006, USA

Received 28 September 2000; received in revised form 14 December 2000; accepted 14 December 2000

Abstract

Background: There are a variety of manual bagging devices used for neonatal resuscitation. To our knowledge, there has been no comparison of the ability of different operators to utilize such devices for the delivery of predetermined inspiratory and end-expiratory pressures. In addition, the use of prolonged inflation may be of benefit for infants who require bag and mask ventilation, and there has been no evaluation of the ability of a variety of operators to reliably deliver such breaths using currently available equipment. **Methods:** We utilized a neonatal manikin (Laerdal Armonk, NY) with a functional larynx and lungs, and a clear cushioned mask (Owens-BriGam, Morganton, NC). We studied a latex-free disposable anesthesia type bag (Model 5126 Vital Signs, Totawa, NJ), a Jackson-Rees (JR) type anesthesia bag (Model E191 Anesthesia Associates, San Marcos, CA) fitted with a Norman elbow and a flow-control tail-piece (Dupaco, Oceanside, CA), and the Neopuff (Fisher and Paykel, Auckland, New Zealand), an FDA approved mechanical device that is flow-controlled and pressure-limited, specifically designed to facilitate neonatal resuscitation. The ventilating pressures were continuously recorded throughout the process. We evaluated neonatal nurses, neonatal nurse practitioners, neonatal staff and fellows, pediatric residents and neonatal respiratory therapists. **Results:** The peak inspiratory pressure (PIP) was significantly different between operators using either anesthesia bag, $P < 0.001$. Similar results were found for positive end-expiratory pressure (PEEP) with a significant difference among the operator groups, $P < 0.001$. All the differences in post hoc analysis were between the therapists and the other groups, $P < 0.05$. Therapists produced significantly higher pressures than the other groups for both PIP and PEEP ($P < 0.001$). The PIP was similar for all groups using the Neopuff device. The PIP and PEEP delivered by the Neopuff differed from the other two devices independent of the operators ($P < 0.05$). On post hoc analysis, there was a significant difference between the disposable anesthesia bag and Neopuff for both PIP and PEEP for the therapists, whereas among the non-therapists, there was a difference in PIP with the JR device producing a greater PIP (26.6 ± 3.8 cmH₂O) compared with the Neopuff and disposable anesthesia bag (24.8 ± 1.1 cmH₂O, 24.8 ± 4.3 cmH₂O). The level of PEEP was significantly different among all three devices for the non-therapists (1.3 ± 1.6 cmH₂O, Disposable; 2.9 ± 1.2 cmH₂O, JR; 4.7 ± 0.5 cmH₂O, Neopuff; $P < 0.05$). Only the therapists were able to consistently deliver PEEP with the anesthesia bags, whereas all operators could generate the target PEEP with the Neopuff ($P < 0.05$). We compared the pressure delivered during the first second to the pressure delivered during the fifth second during prolonged 5-s inflations. The absolute differences between the first and fifth second for the Neopuff versus the anesthesia bags were significantly different with a median of 7.1 cmH₂O for the anesthesia bags compared with 0.2 cmH₂O for the Neopuff, $P < 0.001$, reflecting the difficulty in obtaining and maintaining the target inflation pressures. **Conclusions:** Our experience suggests that the Neopuff, a purpose-built neonatal resuscitator ventilator, facilitates the delivery of the desired airway pressures while maximizing the operators ability to obtain and maintain a patent airway, and facilitates the delivery of prolonged inflations. Further research is required to determine the clinical benefit of end-expiratory pressure and prolonged inflations in neonatal resuscitation. © 2001 Elsevier Science Ireland Ltd. All rights reserved.

Keywords: Anesthesia; Device; Neonatal resuscitation; Positive end-expiratory pressure; Prolonged inspiration; Training

* Corresponding author. Tel.: +1-619-5433759; fax: +1-619-5433812.
E-mail address: nfiner@ucsd.edu (N.N. Finer).

Resumo

Introdução: Existe no mercado uma grande variedade de dispositivos para ventilação manual de recém nascidos. Que tenhamos conhecimento nunca houve nenhum estudo comparativo destes vários dispositivos no que diz respeito á utilização por diferentes operadores e a sua capacidade para administrar pressão inspiratória predefinida e pressão no final da expiração. Para além disso os recém nascidos podem beneficiar com uma insuflação prolongada e também a capacidade de o fazer usando os vários equipamentos nunca foi estudado. **Método:** Utilizamos um manequim neonatal (Laerdal Armonk, NY) com pulmões e laringe e uma máscara facial almofadada transparente (Owens-BriGam, Morganton, NC). Estudamos vários tipos de dispositivo de ventilação: Balão sem látex irrecuperável (Model 5126 Vital Signs, Totawa, NJ); Um balão tipo Jackson Rees (Model E191 Anesthesia Associates, San Marcos, CA) e o Neopuff (Fisher and Paykel, Auckland, New Zealand). Este ultimo é um dispositivo especificamente desenhado para facilitar a reanimação neonatal, controlado por fluxo e limitado por pressão e aprovado pela FDA. Foram registadas de forma contínua as pressões de ventilação. Foram avaliados vários operadores: enfermeiros e enfermeiros em treino de neonatologia; Internos complementares de Pediatria, Especialistas de Pediatria e ainda cinesioterapeutas neonatais. **Resultados:** As pressões de pico inspiratórias (PPI) foram diferentes entre os operadores usando qualquer dos dispositivos ($p < 0.001$). O mesmo aconteceu com a pressão positiva no fim da expiração (PEEP) ($p < 0.001$). Os cinesioterapeutas originaram pressões maiores, PPI e PEEP, que os outros operadores ($p < 0.001$). A PPI foi igual para todos os operadores usando o Neopuff. A PPI e PEEP resultantes do uso do Neopuff foi independente do operador. O nível de PEEP foi diferente entre os 3 dispositivos para os não cinesioterapeutas (1.3 ± 1.6 cmH₂O, balão irrecuperável; 2.9 ± 1.2 cmH₂O, JR; 4.7 ± 0.5 , Neopuff; $p < 0.05$). Apenas os cinesioterapeutas conseguiram gerar PEEP de forma consistente com os balões anestésicos enquanto todos o conseguiram fazer com o Neopuff ($p < 0.05$). Comparamos a pressão ao primeiro e quinto segundos na insuflação de 5 segundos. As diferenças entre o Neopuff e os outros dispositivos foram significativamente diferentes com uma mediana de 0.2 e 7.2 cm H₂O respectivamente ($p < 0.001$), refletindo a dificuldade em manter as pressões de insuflação alvo. **Conclusões:** A nossa experiência sugere que o Neopuff facilita a administração da pressão desejada, maximizando a capacidade do operador e facilitando a administração de insuflações prolongadas. Mais investigação é necessária para determinar o beneficio clínico da PEEP e da insuflação prolongada na reanimação neonatal. © 2001 Elsevier Science Ireland Ltd. All rights reserved.

Palavras chave: Anestesia; Dispositivo; Ressuscitação neonatal; PEEP; Inspiração prolongada; Formação

1. Background

At the present time, the need for resuscitation is greater in the neonate than in any other age group. The Neonatal Resuscitation Program (NRP) was developed by the American Academy of Pediatrics and the American Heart Association and endorsed in 1987 and revised thereafter [1]. The course has been widely taught in the United States and has become the standard of care in newborn resuscitation. Competency in the course material is demonstrated by successful completion of a written and performance evaluation (megacode). Renewal of competency is required every 2 years. It is assumed that individuals who have completed the NRP course will follow the NRP guidelines. In 1998, Kaczorowski et al. [2] showed a significant deterioration of resuscitation knowledge and skills, when providers were re-tested 6–8 months after completion of the NRP course. Another report noted that knowledge, but not skill performance, was maintained at 6 months following the teaching of a neonatal resuscitation program [3].

We previously developed a quality assurance project to assess the performance of neonatal resuscitation using a video camera in one of our operating rooms in our obstetrical unit [4]. We noted that the failure of infants to respond to bag and mask ventilation was related to inappropriate application of the mask and inability to obtain and maintain an adequate pressure in the bag,

resulting in failure to achieve adequate chest expansion possibly secondary to airway obstruction. These results were consistent with previous observations that a common reason for poor Apgar scores was the failure to initiate and maintain adequate ventilation [5].

The use of prolonged inflations for infants who require bag and mask ventilation has been shown to produce a more rapid establishment of functional residual capacity (FRC), which is necessary to improve oxygenation, and to allow inflation without a significant opening pressure [6]. These observations were made almost 20 years ago, and have been reinforced by further prospective observations [7] and recommendations in the British literature [8].

In spite of the above experiences, the use of a prolonged inspiratory time breath of any duration is not a part of the teaching of the NRP, although individual resuscitators may utilize such a strategy. The International Liaison Committee on Resuscitation recently issued a statement on resuscitation of the newly born infant [9] and noted that 'If assisted ventilation is given, higher inflation pressures and longer inflation times may be required for the first several breaths than for subsequent breaths.' The statement went on to indicate that 'Some experts suggest very long inflation times (2–3 s) for initial inflations [6], but this has not been accepted for universal recommendation.' As previously stated, we believe that the evidence which exists to date suggests that such an approach may be beneficial and should be prospectively evaluated.

Neonatal resuscitation is usually performed using either self-inflating bags or anesthetic type devices that are flow driven. The delivery of longer inflation time breaths requires a larger bag volume using self-inflating devices, and even the larger bags may be inadequate for 3–5-s inflation. In addition, the use of anesthesia bags requires the operator to use one hand to squeeze the device and adjust the flow while the other is free to obtain an adequate seal between the mask and the infants' face. Achieving such a seal can be problematic. Simpler devices have been suggested that allow the use of two hands to hold the mask on the face while cycling can be performed using a finger of one hand. Such T-piece devices have been previously described, and are used in routine fashion by some centers [7].

We believe that the use of longer inflation times may be of benefit for neonatal resuscitation. However, before such an approach can be tested, we felt that we needed to evaluate the ability of typical resuscitators to effectively deliver both standard and prolonged inflations. In this study, we compared the use of two currently utilized types of anesthesia bags with a purpose-built FDA approved device specifically designed to facilitate neonatal resuscitation.

2. Methods

We utilized a neonatal manikin (Laerdal Armonk, NY) with a functional larynx and lungs, and placed the manikin on a flat table at the height of the resuscitation radiant warmers in our delivery areas. A clear cushioned mask (Owens-BriGam, Morganton, NC) was chosen to be the correct size for this manikin. Flow dependent anesthesia bags attached to wall-mounted flow meters identical to those utilized for neonatal resuscitation in our hospital were placed next to the manikin with the flow-controller open. We studied a 500 ml latex-free disposable anesthesia type bag (Model 5126 Vital Signs, Totawa, NJ), a 500 ml Jackson-Rees type anesthesia bag (Model E191 Anesthesia Associates, San Marcos, CA) fitted with a Norman elbow and a flow-control t-piece (Dupaco, Oceanside, CA), and the Neopuff (Fisher and Paykel, Auckland, New Zealand), a mechanical device that is flow-controlled and pressure-limited specifically designed to facilitate neonatal resuscitation. All tested devices were FDA approved. A large manometer, similar to those used in our delivery rooms was placed at eye level, in view of the resuscitators.

The system was connected to a pressure transducer (LCVR \pm 50 cmH₂O, Celesco, Canoga Park, CA), positioned on the table at the level of the manikin, directly connected to an analog to digital converter (Model # 220, Dataq Instruments Inc., Akron, OH) and a dedicated laptop computer. The ventilating pressures

were continuously recorded throughout the evaluations. The data was acquired using CODAS (Dataq Instruments Inc.) in operator specific files for later analyzes.

We evaluated neonatal nurses, neonatal nurse practitioners, neonatal faculty, fellows and pediatric residents, and respiratory therapists over 2 days. Each prospective resuscitator was previously familiar with the anesthesia bags and was instructed in the use of the Neopuff (Fisher and Paykel). This device has a t-piece that attaches to a mask, and to a flow-controlled pressure-limited delivery system. The inspiratory pressure can be set to a determined level, and a twist valve at the top of the t-piece determines the end-expiratory pressure. A maximum pressure relief can also be set.

The participants were asked to ventilate the manikin with a bag and mask using all three devices, for 30 s at a rate of 30 breaths per minute, a peak inspiratory pressure (PIP) and positive end-expiratory pressure (PEEP) of 25 and 5 cmH₂O, respectively. Then they were to deliver a breath of 5 s duration, followed by a further 30 s of bag and mask ventilation, and a second 5-s inflation.

The results of the acquired data were placed in spreadsheets and analyzed using SigmaStat software (SPSS, Inc., Chicago, IL). The devices and operators were compared using a two-way analyses of variance (ANOVA), and post hoc testing was performed using Tukey's test, with $P < 0.05$ considered statistically significant.

3. Results

We evaluated five pediatric residents, five nurses, four neonatologists, six neonatal fellows, two neonatal nurse practitioners and five neonatal respiratory therapists. There were no significant differences in the rate of ventilation between groups of operators and anesthesia bags, and these results will not be presented. The PIP was significantly different between operators using either anesthesia bag, $P < 0.001$. Similar results were found for PEEP with a significant difference among the operator groups, $P < 0.001$. All the differences in post hoc analysis were between the therapists and the other groups, $P < 0.05$. The PIP was similar for all groups using the Neopuff device (Table 1).

Because the differences in operators were all between the respiratory therapists and the other groups, all subsequent comparisons are presented between the therapists and the other operators. The therapists produced significantly higher pressures than the other groups for both PIP and PEEP using the anesthesia bags ($P < 0.001$). On the two-way ANOVA analysis for PIP, the Neopuff differed from the other two devices independent of the operators ($P < 0.05$). On post hoc analysis, there was a significant difference between the

disposable anesthesia bag and Neopuff for both PIP and PEEP for the therapists, whereas among the non-therapists, there was a difference in PIP between the two anesthesia bags, with the JR anesthesia device producing a greater PIP (26.6 ± 3.8 cmH₂O) compared with the Neopuff (24.8 ± 1.1 cmH₂O) and disposable anesthesia bag (24.8 ± 4.3 cmH₂O). The level of PEEP was significantly different among all three devices for the non-therapists (1.3 ± 1.6 cmH₂O, disposable anesthesia bag; 2.9 ± 1.2 cmH₂O, JR anesthesia bag; 4.7 ± 0.5 cmH₂O, Neopuff; $P < 0.05$). As can be seen from Table 1, only the therapists were able to consistently deliver PEEP with the anesthesia bags, whereas all operators could generate the target PEEP with the Neopuff ($P < 0.05$).

In an effort to evaluate the ability to provide prolonged inflations, we compared the pressure delivered at the first second to the pressure delivered at the fifth second. There was essentially no difference between these values with the Neopuff (25.0 ± 0.6 to 25.1 ± 0.7 cmH₂O), whereas the disposable anesthetic bag had a mean value of 22.2 ± 5.7 cmH₂O at 1 s compared to 20.4 ± 8.5 cmH₂O at 5 s. The absolute differences between the first and fifth second, that is the differences in pressure including increases or decreases, expressed as the absolute value, not corrected for sign, was significantly different for the Neopuff versus the anesthesia bags with a median of 7.1 ± 0.2 cmH₂O for the anesthesia bags compared with 0.2 cmH₂O for the Neopuff, $P < 0.001$, reflecting the difficulty in obtaining and maintaining the target inflation pressures. The minimum and maximum pressures seen with the anesthesia bags at the fifth second was 17–36 cmH₂O compared to the values for the Neopuff of 26.3–22.8 cmH₂O. The actual pressure wave forms generated by representative operators are shown in Fig. 1.

4. Discussion

Our results have demonstrated that the bag and mask ventilation skills of a group of operators, as assessed on a neonatal manikin, vary by individuals and training. In our unit, the respiratory therapists attend all high-risk deliveries and have historically taken a principal role in providing the bag and mask ventilation in the delivery area. Their ability to produce more consistent peak pressures and PEEP reflects their continued exposure and experience, and familiarity with the devices. There have been few studies that have evaluated the actual bagging skills of groups of operators using various devices [10]. One such study suggested that the use of a pressure manometer resulted in higher mean airway pressures while reducing the variation in delivered pressures [11]. Kanter [12] evaluated the ability pediatric residents, pediatric intensive care nurses, and respiratory therapists to deliver adequate ventilation to a neonatal manikin. They reported that self-inflating bags delivered better minute ventilation than anesthesia bags, and observed a tendency to overventilate and use excessive pressures. In addition, they reported that technical difficulties with the anesthesia bags resulted in a reduced level of ventilation. These problems included difficulty in selecting the appropriate gas flow rate and setting the relief valve such that there was difficulty in maintaining adequate bag volume which resulted in interruptions of ventilation for at least 5 s, problems that we have frequently observed during actual resuscitations. Our observations suggest that the resuscitator (Neopuff) was effective in reducing the variation in delivered pressures, and allowed delivery of the target pressures more reliably than either bagging device, no doubt related to the simplicity of operation. Using this device, the operators

Table 1
PIP and PEEP for the different devices comparing respiratory therapists to non-therapists (all values are cmH₂O)

	Total		Respiratory therapists		Non-respiratory therapists	
	PIP	PEEP	PIP	PEEP	PIP	PEEP
<i>Disp. Bag</i>						
Mean (S.D.)	25.7 (4.3)	1.9 (1.9)	28.3 (2.4)	3.4 (1.8)	24.8 (4.3)	1.3 (1.6)
Median	26.5	1.1	27.7	3.1	25.6	0.6
Min.	8.2	0	25.0	0.1	8.2	0
Max.	34.4	6.8	34.4	6.8	32.7	5.6
<i>Anesth. bag</i>						
Mean (S.D.)	26.6 (3.7)	3.3 (1.2)	26.7 (3.2)	4.2 (0.5)	26.6 (3.8)	2.9 (1.2)
Median	26.7	3.8	25.35	4.3	26.6	2.7
Min.	17	1.4	23.3	3.2	17.0	1.4
Max.	34.9	6.8	34.9	4.9	34.9	6.8
<i>Neopuff</i>						
Mean (S.D.)	24.9 (1.1)	4.7 (0.4)	25.1 (0.7)	4.8 (0.2)	24.8 (1.1)	4.7 (0.5)
Median	25.2	4.9	25.2	4.9	24.8	4.9
Min.	19.9	2.8	23.5	4.3	19.9	2.8
Max.	26.2	5.2	26.2	5.2	26.0	5.2

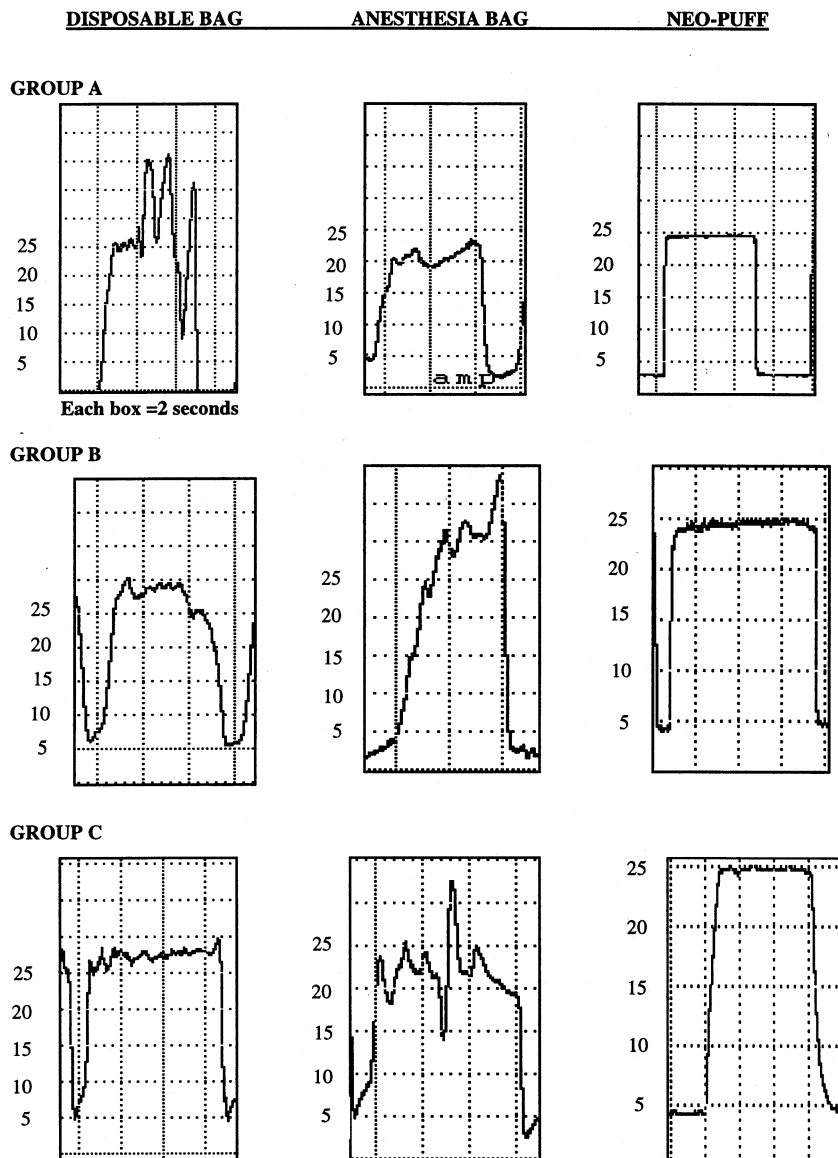


Fig. 1. Representative tracings from each anesthesia bag and the Neopuff® for a 5-s inflation. The scales are variable between figures, as these represent actual recordings obtained at different gain settings. The actual scale is indicated on each figure: group A, pediatric resident; group B, neonatologists; group C, neonatal respiratory therapists. Each vertical box represents 5 cmH₂O and each horizontal box represents 2 s.

could use two hands to affix the mask to the face and achieved better seal between the mask and airway. In addition, this device obviates the need for the operator to control the leak, or flow for the delivery of the PIP and PEEP. The flow-controllers on the anesthesia bags used for this study allow for a variable orifice. However, once set, the orifice is fixed during the process of ventilating. It is not possible to maintain PEEP without either momentarily decreasing the size of the orifice or increasing flow. Most experienced operators have developed a method of partially shutting off flow out of the controller while ventilating so that all the excess flow does not leave the bag, producing a partially empty bag with little or no

PEEP. Despite the fact that several of our non-therapist operators had over 20 yr of experience, overall mean PEEP values were 1.3 cmH₂O for the disposable anesthesia bag and 2.9 for the JR anesthesia bag. The Neopuff resuscitator yielded mean PEEP values of 4.7 cmH₂O.

PEEP has been shown to be of benefit in maintaining FRC. Although no formal recommendation to date has been made about maintaining PEEP in the delivery room setting, continuous positive airway pressure (CPAP) appears beneficial during cardiopulmonary resuscitation [13]. Gregory et al. in 1971 [14] demonstrated that the early use of CPAP in newborn infants with respiratory distress improved oxygena-

tion, and these observations were followed by prospective studies that demonstrated improved survival in premature infants treated with early CPAP [15]. In addition, the use of early CPAP appears to decrease the need for subsequent surfactant use and mechanical ventilation in the premature infant [16,17]. It is of interest that early CPAP is a frequently used support modality for premature infants with respiratory distress [18], and end-expiratory pressure is used for all neonates requiring mechanical ventilation, and yet there is no current recommendation for the use of CPAP or PEEP during neonatal delivery room resuscitation [1].

The response of neonates to resuscitation has been carefully evaluated in a series of studies in small numbers of infants at City Hospital in Nottingham, England. These infants were intubated at birth and were instrumented with a flow transducer, an airway pressure monitor, and an esophageal catheter. These studies determined that asphyxiated infants born by cesarean section required a significant opening pressure that had to be exceeded before air entered the lung [19,20]. They also noted that FRC did not develop until the infant made respiratory efforts, and increased following a stepwise increase in tidal volume [19,21]. On careful examination of the volume tracing, it was noted that air was still entering the chest at the end of a 1-s inflation, and suggested that a longer period of inspiration may increase the actual achievable tidal volume. In a study of nine asphyxiated infants requiring intubation, five received an initial slow rise inflation and four received an initial square wave inflation, with a mean duration of the prolonged breath of 5 s [6]. All nine infants formed an FRC but no opening pressure was noted in four of the five infants resuscitated with the slow rise inflation, and both methods produced better tidal volumes than a 1-s inflation, 33.6 versus 18.6 ml. It was postulated that the longer inflation produced more even air distribution within the lung, and facilitated lung fluid reabsorption. They noted that before the onset of respiration, there is virtually no pulmonary blood flow, and demonstrated that using pressures of up to 30 cmH₂O there was less than 5 cmH₂O pressure conducted to the mediastinum. The pressures utilized for these resuscitative breaths were less than that seen during spontaneous first breaths and thus the risk of air leak was postulated to be minimal, and did not occur in these nine infants. More recently, it was found that premature infants who did not form an FRC were more likely to develop hyaline membrane disease requiring mechanical ventilation [22].

Lindner et al. [23] from Ulm, Germany retrospectively evaluated the use of a very prolonged inspiration of 15 s duration as part of a novel protocol for infants of less than 1000 g birth weight (extremely

low birth weight, ELBW). Thus after suctioning, a pressure controlled (20 cmH₂O) 15-s inflation of the lungs was given via a nasopharyngeal tube while holding the other nostril and mouth occluded, using a mechanical ventilator. This procedure was repeated at 25 cmH₂O if the heart rate remained <100 bpm and/or if the infant remained cyanotic. The infants were then placed on CPAP or continued nasal ventilation until spontaneous respirations were present, and intubated if they did not improve. These authors reported that their approach resulted in fewer ELBW infants requiring initial intubation in comparison to infants treated 2 years earlier. No infant treated by this approach had an air leak at the time of NICU admission. This study evaluated a number of changes in the early resuscitation and management of ELBW infants, including the acceptance of higher Pa_{CO₂} levels before intervening, and it is not possible to determine the effect of one of the interventions on overall outcomes. The use of a resuscitation breath of 15-s duration in the manner described in this study may not be as safe as shorter breaths, and requires further prospective evaluation before it can be endorsed.

Thus, there appears to be ample initial evidence that the use of a prolonged inflation may be beneficial for infants who require bag and mask ventilation. Before attempting to initiate the use of such prolonged inflations, we wished to evaluate the ability of providers in our institution to deliver target pressures and prolonged inflations using our current devices as well as a newer device that has been purposely developed to facilitate neonatal resuscitation. This device is similar in concept to that described and utilized by Milner [6].

Our results suggest that the Neopuff resuscitator is a simple device that can effectively deliver target PIP and PEEP better than current devices even in the hands of our experienced resuscitators. In addition, the more inexperienced operators show even a greater benefit when using this device. We believe that the major advantages of this device include the ability of the operator to use two hands to obtain and maintain an adequate airway seal, the ability to reliably deliver a predetermined level of both PIP and PEEP, even during prolonged inflations and protection against the use of unintentional excess pressures. Using the anesthesia bags, most operators were unable to deliver a prolonged inflation of 5-s duration while maintaining a constant PIP, whereas with the Neopuff, the PIP remained constant throughout the 5 s (Fig. 1). We observed that delivered pressures could be as high as 15 cmH₂O above the target pressures using the anesthesia bags, which could result in significant unintended barotrauma.

5. Conclusion

We believe that further research needs to be performed to evaluate the use of CPAP and PEEP, and the use of prolonged inflations as part of the initial resuscitation of neonates, involving not only the use of these modalities, but evaluating the most optimal equipment to provide such support. Our experience suggests that the Neopuff, a unique neonatal resuscitator ventilator, facilitates the delivery of desired airway pressures while allowing the operators to use both hands to attempt obtain and maintain a patent airway.

Acknowledgements

The authors wish to thank all of our respiratory therapists, neonatologists and fellows, neonatal nurse practitioners and nurses who participated in this evaluation. We also thank Chris Hutchinson of Fischer and Paykel for providing the Neopuff for this evaluation.

References

- [1] Kattwinkel J, editor. The textbook of neonatal resuscitation. 4th ed. The AHA/AAP Neonatal Resuscitation Program Steering Committee, American Heart Association, 2000.
- [2] Kaczorowski J, Levitt C, Hammond M, et al. Retention of neonatal skills and knowledge: a randomized controlled trial. *Fam Med* 1998;30(10):705–11.
- [3] Dunn S, Niday P, Watters NE, McGrath P, Alcock D. The provision and evaluation of a neonatal resuscitation program. *J Contin Educ Nurs* 1992;23(3):118–26.
- [4] Carbine D, Finer N, Knodel E, Rich W. Video recording of neonatal resuscitation. *Pediatrics* 2000;106:654–8.
- [5] Perlman JM, Risser R. Cardiopulmonary resuscitation in the delivery room. Associated clinical events. *Arch Pediatr Adolesc Med* 1995;159:20–5.
- [6] Vyas H, Milner AD, Hopkin IE, et al. Physiologic responses to prolonged and slow rise inflation in the resuscitation of the asphyxiated newborn infant. *J Pediatr* 1981;99:39–65.
- [7] Hoskyns EW, Milner AD, Hopkin IE. A simple method of face mask resuscitation at birth. *Arch Dis Child* 1987;62:3766–8.
- [8] Milner AD. Resuscitation of the newborn. *Arch Dis Child* 1991;66:66–9.
- [9] Kattwinkel J, Niermeyer S, Nadkarni V, Tibballs J, Phillips B, Zideman D, et al. ILCOR advisory statement: resuscitation of the newly born infant – an advisory statement from the Pediatric Working Group of the International Liaison Committee on Resuscitation. *Pediatrics* 1999;103(4):E561–E5613.
- [10] Terndrup TE, Kanter RK, Cherry RA. A comparison of infant ventilation methods performed by prehospital personnel. *Ann Emerg Med* 1989;18(6):607–11.
- [11] Karsdon J, Stijnen T, Berger HM. The effect of a manometer on the mean airway pressure during hand ventilation, an in vitro study. *Eur J Pediatr* 1989;148(6):574–6.
- [12] Kanter RK. Evaluation of mask-bag ventilation in resuscitation of infants. *Am J Dis Child* 1987;141:761–3.
- [13] Hevesi ZG, Thrush DN, Downs JB, Smith RA. Cardiopulmonary resuscitation – effect of CPAP on gas exchange during chest compressions. *Anesthesiology* 1999;90(4):1078–83 ISSN: 0003-3022.
- [14] Gregory GA, Kitterman JA, Phibbs RH, et al. Treatment of the idiopathic respiratory distress syndrome with continuous positive airway pressure. *N Engl J Med* 1971;284:1333–40.
- [15] Rhodes P, Hall RT. CPAP delivered by face mask in infants with the idiopathic respiratory distress syndrome: a controlled study. *Pediatrics* 1973;52:17–21.
- [16] Verder H, Albertsen P, Ebbesen F, Greisen G, Robertson B, Bertelsen A, et al. Nasal continuous positive airway pressure and early surfactant therapy for respiratory distress syndrome in newborns of less than 30 weeks' gestation. *Pediatrics* 1999;103(2):E241–6.
- [17] Gittermann MK, Fusch C, Gittermann AR, et al. Early nasal continuous positive airway pressure treatment reduces the need for intubation in very low birthweight infants. *Eur J Pediatr* 1997;156:384–8.
- [18] Van Marter LJ, Allred EN, Pagano M, Sanocka U, Parad R, Moore M, et al. Do clinical markers of barotrauma and oxygen toxicity explain interhospital variation in rates of chronic lung disease? The Neonatology Committee for the Developmental Network. *Pediatrics* 2000;105(6):1194–201.
- [19] Boon AW, Milner AD, Hopkin IE. Physiological responses of the newborn infant to resuscitation. *Arch Dis Child* 1979;54:492.
- [20] Hoskyns EW, Milner AD, Boon AW, Vyas H, Hopkin IE. Endotracheal resuscitation of preterm infants at birth. *Arch Dis Child* 1987;62:663–6.
- [21] Boon AW, Milner AD, Hopkin IE. Lung expansion, tidal exchange, and formation of the functional residual capacity during resuscitation of asphyxiated neonates. *J Pediatr* 1979;95:1031–6.
- [22] Upton CJ, Milner AD. Endotracheal resuscitation of neonates using a rebreathing bag. *Arch Dis Child* 1991;66:39–42.
- [23] Lindner W, Vossbeck S, Hummler H, Pohlandt F. Delivery room management of extremely low birthweight infants: spontaneous breathing or intubation? *Pediatrics* 1999;103(5):961–7.